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"MICROCOMPUTER PROCESSING AND INTERPRETATION OF SIDE-SCAN SONAR DATA, MID CHESAPEAKE BAY"

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"MICROCOMPUTER PROCESSING AND INTERPRETATION OF SIDE-SCAN SONAR DATA, MID CHESAPEAKE BAY"

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13. ABSTRACT (Maximum 200 words) The EG&G Model 260-TH side-scan sonar is a high resolution shallow water mapping instrument which produces detailed images if the seafloor over which it is towed. Side-scan sonar is used for a variety of applications, including geologic surveying and minehunting. Raw side-scan data, stored on digital tape, contains many geometric and radiometric errors. Post-processing is necessary to correct these errors and maximize the usefulness of the data. The Borland Pascal program SIDESCAN has been developed for sonograph display and analysis. The program runs on standard MS-DOS microcomputers and displays fully corrected image segments and mosaics. Merging satellite navigation data with the side scan imagery yields ground registered images, allowing a user to accurately locate (in latitude/longitude coordinates) and measure any bottom feature or overlay bathymetric contours. Digital mosaics of the Chesapeake Bay bottom near the Severn River demonstrate the power the of the process. Images of mud flats, sandy regions, and oyster bars show the variability of sediment types in the Bay, Many features, both natural and man made, have also been identified, including buoys, the wreckage of a barge, ridges and mounds, a deep channel, submarine cables, and trawl marks.

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Abstract. The EG&G Model 260-TH side-scan sonar is a high resolution shallow water mapping instrument which produces detailed images of the seafloor over which it is towed. Side-scan sonar is used for a variety of applications, including geologic surveying and minehunting. Raw side-scan data, stored on digital tape, contains many geometric and radiometric errors. Post-processing is necessary to correct these errors and maximize the usefulness of the data.

The Borland Pascal program SIDESCAN has been developed for sonograph display and analysis. The program runs on standard MS-DOS microcomputers and displays fully corrected image segments and mosaics. Merging satellite navigation data with the side scan imagery yields ground registered images, allowing a user to accurately locate (in latitude/longitude coordinates) and measure any bottom feature or overlay bathymetric contours. Digital mosaics of the Chesapeake Bay bottom near the Severn River demonstrate the power of the process.

Images of mud flats, sandy regions, and oyster bars show the variability of sediment types in the Bay. Many features, both natural and man made, have also been identified, including buoys, the wreckage of a barge, ridges and mounds, a deep channel, submarine cables, and trawl marks.

Keywords: Side-scan sonar, Chesapeake Bay, microcomputer digital image processing

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1. Introduct'on

1.1. History of Side-Scan Sonar

Prior to the 1950s, scientists could only speculate on the nature of the bottoms of the oceans and deep lakes. Primitive sounding devices provided a vague picture of seafloor morphology, while isolated bottom samples hinted at sediment composition. Based on this meager data, researchers pictured the ocean floor as a mainly flat, featureless plain blanketed with a layer of sediment.

Several developments in the 1960s sparked intense interest in the examination of the ocean bottoms. The Vine and Matthews seafloor spreading hypothesis, through its widespread acceptance, shattered the belief that the ocean floors were passive, flat basins. Deep Sea Drilling Project core data and narrow beam echosounder bathymetry data continued to provide evidence that the seafloor was a dynamic surface dotted with a variety of features and sediment types. Finally, firsthand glimpses of submarine ridges through the portholes of submersibles intrigued scientists and inspired a clamor for more detailed and complete exploration. Study of the deep ocean floor required a tool which could quickly and accurately map large portions of the bottom [*Johnson and Helferty*, 1990].

Since the 1800s, scientists have known of the excellent transmission of acoustic energy in seawater. This knowledge, coupled with new electronic technology, led researchers to develop the first sonars (SOound Navigation And Ranging). Although these systems had been used widely in World War I to track enemy ships and submarines, it was impractical to use them to chart ocean bathymetry. Starting in World War II, however, Harry Hess used echosounder data collected by Navy warships to support what later became his plate tectonics theories. In the 1950s, British and German mariners invented the first sonars which imaged large swaths of seafloor to chart dangerous shoal areas. The images, or sonographs, formed by the interaction of sound pulses with the bottom, were blocky and difficult to interpret [*Stride*, 1992].

EG&G Marine Instruments researcher Dr. Harold "Doc" Edgerton used a similar technique in 1967. By turning his "sub bottom profiler" so that the beam of sound energy would strike the bottom at an angle, instead of straight down, he found that he could identify anomalies on the bottom far away from the ship, perpendicular to the ship's track. Hard targets reflected the most energy back towards the transducer, thus producing the brightest images. This simple experiment formed the framework for the future development of high resolution shallow water mapping instruments [*Thekkethala and Spruance*, 1992].

In the 1970s and 1980s, engineers further improved side-scan sonar resolution until sonographs resembled photographs of the bottom. However, even some of the most modern side-scan sonographs still contain geometric and radiometric errors (spatial and return strength errors, respectively) because of the side looking nature of the sonar and the behavior of sound in the water column. Image processing techniques must be applied to side-scan data in order for features to retain their correct undistorted shapes. Corrected and enhanced digital side-scan sonar mosaics enable scientists or military tacticians to examine a large area of seafloor projected on a map grid for bathymetric features, sediment types, or man made objects [*Johnson and Helferty*, 1990].

1.2. Side-Scan Sonar Applications

High resolution side-scan sonars have a wide array of military, commercial, and scientific uses. They are especially useful to one of the fastest growing Naval communities, the mine warfare force, because of their ability to quickly scan large swaths of seabed and water column. They have been used extensively by salvage companies for locating shipwrecks and downed aircraft. Geologists use the sonar to analyze bottom topography and features, sedimentological framework, biological bottom communities, bed roughness properties, sand waveforms, and hurricane effects. Finally, marine biologists can use the sonar to detect and quantify communities of benthic organisms such as oysters.

One of the deadliest threats to surface shipping since the 1700s has been the mine. Mine damage to *U.S.S. Tripoli* and *U.S.S. Princeton* during Desert Storm highlights the importance of this warfare area. The former Soviet Union, with an inventory of as many as 450,000 mines, is a concern not only because of current political instability, but also because of unscrupulous selling practices. Many Third World nations have recognized the brutally effective value of the mine, and some nations have already stockpiled more than 100,000 mines [*Murphy*, 1993]. One of the fundamental tools in use among the minehunting forces of the world is high resolution side-scan sonar. These sonars can identify both bottom and floating mines. A database, compiled during peacetime, of normal side-scan returns in a given area greatly assists the minehunting process in a wartime situation [*Thekkethala and Spruance*, 1992]. As the focus of naval warfare shifts to regional conflicts in littoral areas, more accurate and reliable side-scan systems will be called upon to neutralize the mine threat.

The U.S. Navy also uses side-scan sonars in diving and salvage operations. CDR Green (personal communication, 1994) of the Deep Submergence Unit in Coronado, California stressed the importance of their side-scan sonar in locating downed aircraft and submarines. By pinpointing the location of wreckage before starting salvage operations, critical underwater time is saved.

Geologists have used side-scan sonars for a variety of applications. In Buzzards Bay, *Menzie et al.* [1982] used an EG&G SMS 960 side-scan sonar to study a dump site located in 7-18 m of water. One-meter features were clearly discerned with the sonar. The topography was classified into six major topographic regions, including flat areas, wave forms, and cratered bottom areas. In addition, they used the sonar to identify sediment types and stages of benthic biologic succession.

Bothner et al. [1992] mapped the textural and morphological variations in the western Massachusetts Bay region to determine a suitable spot for treated sewage release from Boston. They predicted paths for contaminant transport and also studied the habitats of sediment dependent marine organisms. Their data, comprised of bathymetric maps, geologic maps, and side-scan mosaics, was stored on CD-ROM. *Knebel et al.* [1992] also used a shallow water side-scan to study this area, focusing on Boston Harbor.

Side-scan sonar data was also used to help classify bottom types in the Potomac River estuary [*Knebel et al.*, 1981], the Delaware Bay [*Knebel*, 1989], the continental shelf waters off the coast of Maine [*Kelley et al.*, 1989], and a nearshore zone along the Rhode Island coast [*Morang and McMaster*, 1980; *Knebel et al.*, 1982]. From this data, geologic histories of the areas were constructed.

In a study of the bed roughness in the lower Chesapeake Bay and the inner continental shelf, *Wright et al.* [1987] classified the bottom into ten different types. They relied primarily upon a 100 kHz fully corrected side-scan sonar for their conclusions. They validated their interpretations with in situ observations by divers. Wave ripples, biological roughness elements such as oyster colonies, and gravelly sediments were all clearly revealed with the side-scan system. From these observations, they made further conclusions about the water flow across these bottom types. *Hobbs* [1986] conducted similar experiments in the southern Chesapeake Bay. He focused on the ability of the high resolution side-scan to resolve small patches of differing sediments.

Green [1986] used a high resolution side-scan sonar to map sand wave morphology near Duck, North Carolina, on the Southern Bight. By matching features, Green constructed a mosaic of the sand ridge area and identified bedforms including sand ridges, megaripples, and smaller wave ripples. *Harris and Collins* [1984] also studied sand waves, though they concentrated on the variations in sand waves imaged in the Bristol Channel due to storm events. *Mann et al.* [1981] classified sandy bedforms based on EG&G side-scan data from Nantucket Shoals.

Severe weather events, such as a hurricane, can cause severe damage to the environment. *Mearns et al.* [1988] compared side-scan sonar sonographs of Onslow Bay, North Carolina, produced before and after Hurricane Diana, and concluded that the seafloor itself suffered no drastic changes as a result of the storm. As side-scan sonar data continues to accumulate, seasonal and annual seafloor changes can be analyzed more accurately.

The oyster bars of the Chesapeake Bay have afforded an excellent opportunity to apply the capabilities of side-scan imaging. Concentrations of oysters, due to their high population density, shell hardness, and shell roughness, appear as extremely high energy returns on a sonograph. *Hobbs* [1988] used a seismic profiler to identify and quantify an oyster bar in the Tangier and Pocomoke Sounds of the Chesapeake Bay. The main limitation to his method was his lack of data coverage. Coupling an echo sounder and a 100 kHz Klien side-scan system, *Dealteris* [1988] found that oyster reefs of oyster density 91/m^2 (confirmed with oyster tongs) were easily discerned. He demonstrated the feasibility of the oyster reef mapping in three tributaries of the Chesapeake Bay.

1.3. Operating Principles

Like any other sonar system, side-scan sonars operate on the principle of timed sound propagation in water. While echo sounders use a single transducer for transmitting and receiving sound energy, the side-scan sonar uses a linear array of interconnected transducers mounted on each side of the torpedo shaped "towfish." Thus, two beams that are wide in the across track dimension but narrow in the along track dimension are produced. These fan-shaped sound pulses, or echoes, propagate outward and down, where they strike the bottom and are either backscattered (reflected back) to the transducers, absorbed by the water column or bottom, specularly reflected away from the transducers, or dissipated through attenuation. After being received by the array of transducers, the echo is transformed into an electric voltage and transmitted to the Model 260-TH processing unit aboard the survey vessel [*Johnson and Helferty*, 1990]. Figure 1 illustrates how a side-scan sonar collects data. The strength of the returned energy depends upon its angle of incidence with the bottom (bathymetry), type of acoustic reflector (sediment hardness), and the surface roughness at the scale of energy used (microtopography). Slopes angled towards the towfish produce strong acoustic returns because more of the energy is reflected back at the transducers. Likewise, hard objects, which are more reflective to sound energy, show up as stronger returns than soft bottoms, which tend to absorb sound energy. Finally, the surface roughness, or microtopography, affects the return by reflecting acoustic energy back to or away from the towfish. A smooth bottom, like a mirror, produces a specular reflection in which the angle of incidence equals the angle of reflection. Thus, the majority of energy incident on a smooth bottom will be reflected away. Rougher bottoms correspond to stronger returns because some portions of the surface will be angled towards the towfish [*Gardner et al.*, 1991]. Finally, some low-frequency, long-range systems such as the Geological Long Range Inclined Asdic (GLORIA) have been known to penetrate the bottom slightly, revealing information about sediment thickness [*Mitchell*, 1993]. The data, or sonograph, stored and printed aboard the research vessel shows the track line of the towfish, the water column, and two greyscale pictures of swaths of the bottom, one on either side of the towfish [*EG&G Marine Instruments*, 1991].

1.4. Interpreting the Sonograph

A side-scan record, or row of data, is produced by the integration of hundreds of returned echoes from the water column and seafloor. Many variables affect the quality of side-scan sonar data in addition to those which produce an image, including environmental conditions (winds, waves, currents, and water density variations), survey vessel course and speed, acoustic noise, towfish depth, range setting, and frequency setting. Figure 2 is an uncorrected side-scan sonograph from the mouth of the Severn River. It shows the vessel track line and two channels of data representing the water column and bottom features to the port and starboard sides of the towfish. White shades represent the strongest returns and black shades the weakest returns. Many other side-scan systems, including the EG&G thermal printer, use an opposite color convention. Occasionally, fish or random particulate matter (collectively known as "sea clutter") produce slightly stronger returns in the water column. The first bottom return is usually discernible as the light line bordering the outside edge of the water column [*Chavez*, 1986]. Features appear as varying shades of grey on either side of the trackline. Acoustic shadows are dark regions where ensonifying energy cannot penetrate. Typically they are found on the sides of elevated features which face away from the towfish. Features in Figure 2 include small round mounds and two ridges. Long dark marks along the sides of the ridges are acoustic shadows, formed as a result of the height of the ridges [*Teleki et al.*, 1981].

1.5. Imaging Errors

Interpretations of sonographs produced by modern side-scan sonars must be tempered with caution. Raw sonographs contain many geometric (shape) and radiometric (return strength) errors. Geometric errors include slant range distortion, anamorphic distortion, and speed variation distortion. Slant range error is introduced in the image because the side-scan circuitry records the returning echoes as a function of the time of travel (yielding the slant distance from the towfish to the bottom), and not the horizontal distance from the nadir of the towfish to the object. Thus, objects appear farther away from the trackline than they should be. The Pythagorean Theorem will be used to correct for this error [*Paluzzi et al.*, 1976; *Burrett et al.*, 1991].

Since sound pulses are transmitted at regular intervals dependent upon the selected range, the along-track dimension of the side-scan image is dependent upon the speed of the ship. The resulting image usually does not have the same along and across track dimensions (known as anamorphic or aspect ratio distortion). To correct for this, an algorithm must be included in the display software that will repeat or omit the necessary number of rows to force the along-track resolution to match the across-track resolution (typically along track data must be repeated three times to produce a square pixel) [*Chavez*, 1986; *Searle et al.*, 1990].

In addition, because the side-scan sonar uses a speed log (measuring the speed of the survey vessel and towfish through the water) to generate its speed data, this may cause distortion if a current is adding to or subtracting from the speed of the towfish over the ground [*Paluzzi et al.*, 1981]. For example, a towfish being pushed ahead by a current will image more of the bottom than the speed log would indicate. This produces an image which is incorrectly compressed in the along-track direction. This error is compensated for by using speed over ground instead of speed through the water. The speed over ground is calculated by introducing satellite derived (GPS) position data into the side-scan records.

Radiometric errors are those which affect the return strength, or digital number (DN) of a pixel. A fully geometrically corrected image still may be difficult to interpret due to the following radiometric errors: far range power drop off (undercorrection of the towfish's time varied gain, TVG), speckle noise, and striping noise [*Chavez*, 1986].

Due to the attenuation of sound as it travels through the water, images become degraded near the edges. The time varied gain circuitry within the towfish automatically applies a correction factor which partially compensates for the attenuation of sound [*Searle et al.*, 1990].

A common problem in both radar and sonar digital images is the presence of "speckle noise." Speckle noise is the random sprinkling of contrasting individual data points in an image. It gives the image a grainy appearance which further complicates feature identification [*Chavez*, 1986].

2. Data Collection

2.1. Equipment Specifications

An EG&G Model 272-TD side-scan "towfish," a torpedo shaped instrument towed behind the survey vessel (YP686), was used to image the mid Chesapeake Bay. Typically the towfish depth is several meters below the water surface, although this varies depending on the amount of cable deployed (usually 25 m) and the speed of YP686 (usually 4-6 knots). The EG&G Model 272-TD towfish's specifications are listed in Table 1. Its lower frequency ("100 kHz") mode was used for this project because strong signal attenuation associated with the higher frequency caused image degradation at ranges in excess of 100 m. This frequency plays an important role in determining resolution, effective range, and image quality [*EG&G Marine Instruments*, 1990; *Johnson and Helferty*, 1990].

Side-scan image resolution is the ability of the side-scan to distinguish between adjacent features, and is ultimately dependent upon the size of the "footprint" of the individual side-scan ping. The maximum across track resolution possible is dependent upon the pulse length and angle between the sound path and thc horizontal (Resolution = dt * c / [2 * cos(Θ)]). For a 0.1 ms pulse length, an assumed sound velocity in water of 1500 m/s, and a 20° look angle, the across track resolution is 8.0 cm. The closer features are to the towfish (bigger Θ), the more difficult they will be to resolve because the "footprint" of the sonar ping will be larger. The maximum across track resolution (Θ = 0°) is dt * c/2, or 7.5 cm. The ideal along track resolution is mainly dependent upon the ping rate. Assuming that only one ping will be in the water column at any time, the maximum ping rate can be calculated. Assuming a speed of sound in water of 1500 m/s, it takes a sonar ping 0.267 seconds to travel to the edge of a 200 m range and back. If the speed of the YP is 6 knots (3.05 m/s), it would cover 0.81 m in the time it takes a ping to depart and return. This along track resolution further degrades with range because the horizontal beam is not constant, but actually spreads (1.2°) with distance from the towfish. Thus, the "footprint" expands in the along track dimension with increasing distance from the towfish (Along track "footprint" = beam spreading angle * range). For a 200 m swath width, this yields a 1.0 m resolution 100 m from the centerline and a 4.2 m resolution at the edge of the image. These resolutions represent the theoretical resolving power of the sonar. Typically, when side-scan sonar images are displayed, resolution degrades further [*Johnson and Helferty*, 1990; *Malinverno et al.*, 1990].

The sonar stores the raw 6-bit 64 DN range backscatter data in 884 bins across track, although this includes data from the water column and beyond the swath width. Both channels of side-scan data are printed with geometric corrections for slant range and anamorphic distortion based on speed through the water on a thermal printer aboard the towing vessel, YP686. In addition, uncorrected side-scan data can be stored on 8mm digital tapes for post-processing. The thermal printer displays 800 pixels per channel per line, thus producing a display resolution of 0.50 m for a 200 m range. The true resolution will actually be worse than this because of ping "footprint" size. Only 16 grey tones can be displayed with the thermal printer.

The 8mm digital tape data was converted to DOS format with NOVA tape utility software. The data can also be copied to 9 track using DEC MicroVax or to DOS format with Exacopy Software for CRZ Development. The data stored on tape is in raw form, uncorrected geometrically or radiometrically except for TVG applied within the towfish circuitry [*EG&G Marine Instruments*, 1991].

After collection, the side-scan data was read and processed with a Borland Pascal [*Borland International*, 1992] program, SIDESCAN, on a standard 486 MS-DOS microcomputer with a super VGA monitor and Exabyte tape drive. There are several advantages to this method. The processing becomes repeatable and very convenient. As new image processing techniques are developed, digital rectification and mosaicking can become even faster and more reliable [*Paluzzi et al.*, 1981]. Also, converting the side-scan data to digital images allows the user to add navigation data, use many image enhancement techniques, or overlay bathymetric contours [*Teleki et al.*, 1981]. With the SVGA monitor, 1024 pixels may be displayed across the screen. If just one channel is displayed, every data point of the original 884 bins can be displayed at least once, although water column data and data beyond the range limit will normally be discarded. If both channels are displayed, the resolution is slightly degraded, but not beyond the typical "footprint" resolution (512 pixels per channel, or an across track resolution of 0.40 m). Also, the pixels are displayed using 64 grey scales, allowing for vastly improved contrast. This contrast can be improved further with many image enhancement techniques.

Odom Echotrac DF3200 depth readings and Magellan NavPro 1000 hand-held

GPS satellite navigation data were used with the side-scan system. The fathometer readings provided an accurate measure of depth (to 0.1 feet or 0.03 m), and the GPS provided a measure of position. The GPS, a standard hand-held civilian unit, is subject to satellite selective availability (intentional degradation by the U. S. military for security purposes). However, position data may be considered to be accurate to within 100 m [*Odom Hydrographic Systems*, 1985; *Magellan Systems Corporation*, 1990]. Position and depth data for each survey run were stored in microcomputer files. Figure 3 shows the relationships between the equipment used and the initial processing steps.

2.2. Study Area

The focus of the side-scan study was the mid Chesapeake Bay region near the mouth of the Severn River. This area was further broken down into five major focus areas: the mouth of the Severn River, the Tolly Point natural oyster bar, the Thomas Point natural oyster bar, the middle region of the Chesapeake Bay, and the axis of the old Susquehanna riverbed in the eastern third of the Chesapeake Bay. These five main survey areas are shown, along with the adjacent coastlines, in Figure 4. None of these areas has ever been the subject of a side-scan study.

At 200 m range, EG&G side-scan data is collected at a rate of 0.36 MB per minute. At 100 m range, since the sonar is transmitting twice as often, the data collection rate is 0.72 MB per minute [*EG&G Marine Instruments*, 1991]. Files as large as 72 MB have been collected. Breaking up the original files into smaller straight segments aids in decreasing processing time because data can be written to the virtual drive, if the computer has enough random access memory (RAM). In addition, straight segments are preferred because data overlap occurs on the inside channel and data gaps on the outside channel during a sharp turn. Table 2 lists the EG&G data files which have been converted to DOS format and split into straight segments.

3. Microcomputer Side-Scan Sonar Image Processing

3.1. Digital Image Processing

Digital image processing techniques were first developed for optical images in the early 1960s. The transition to processing acoustic images has been rather slow in catching up. Digital sonograph image processing is currently at a point where optical image processing was 20 years ago. Acoustic images are limited to using shades of grey to represent return strengths and also lack the resolution of optical images [*Johnson and Helferty*, 1990].

Two broad fields of image processing have been applied to the side-scan sonar imagery with SIDESCAN. The first is image rectification, which is the correction of errors inherent to side-scan data. These include both geometric, or pixel placement, and radiometric, or pixel strength, errors. The second area is image enhancement. Image enhancement techniques such as filtering can be used to produce images which are more easily interpreted by the human operator [*Hall*, 1979].

3.2. SIDESCAN Program Overview

Associate Professor P. L. Guth of the United States Naval Academy Oceanography Department developed a prototype SIDESCAN program for side-scan data display. His program included a number of other graphical options, including backscatter and fish height plotting routines. A subset feature allowed the user to break up large data files. Geometric and radiometric errors were not corrected for, limiting the usefulness of the sonograph display. Basic procedures and capabilities of the original program are listed in Table 3.

New additions to SIDESCAN are also listed in Table 3. The program can now display multiple raw images on a screen, invert the images, and display the data in multiple columns. In addition, all geometric corrections are automatically applied. The user has an option to apply the radiometric corrections, which slows down the display speed. The user also now can choose the digital number (DN) of the first bottom value and the transducer used for determining the fish height (previously, an average was used). A ground registration routine has been implemented, so position coordinates and track headings can be written to side-scan records. Thus, positions and distances can be retrieved while displaying data files. While displaying to the screen, fully corrected images can be copied to a standard raster image file for image enhancement. Also, with the digital mosaicking routine, several files can be written to a map projection, or existing mosaics combined. The step by step procedure for the beginning user to rectify and enhance raw side-scan data is provided in Appendix A. The help files, which explain SIDESCAN's menu choices, are listed in Appendix B, and a complete listing of the new SIDESCAN code can be found in Appendix C.

3.3. Image Rectification

3.3.1. Geometric Corrections

To show the results of applying corrections for geometric and radiometric errors, a single image will be rectified step by step. Figure 5, displayed using the original SIDESCAN, is an image of a buoy and berm in the mouth of the Severn River suffering from all side-scan errors. The buoy and its anchoring chain are indistinguishable due to geometric and radiometric errors.

The two most prevalent geometric errors in shallow water side-scan imagery are those caused by the slant range and the display aspect ratio. Before these can be corrected for, however, the towfish height must be corrected and the water column data must be removed.

The distance from the centerline to the first bottom return can be used to find the towfish height above the bottom. First, a bottom value is selected. This is the digital number value which is strong enough to qualify as the first bottom reading, and is carefully chosen through examination of average return strength graphs. On Figure 6, showing average return strengths from the mid Chesapeake Bay, the average DN near the centerline is 0, representing the water column returns. The quick increase in DN from 0 to 15 represents the transition from the water column to the bottom. Before displaying a line of data, the computer counts through each return strength value for the whole row until a value exceeding the chosen bottom strength constant is reached. The pixel number is saved. Then, when SIDESCAN displays the data, it starts not from the centerline pixel number, but the first bottom value pixel number, eliminating the water column and producing a geometrically correct view of the bottom. The fish height can be computed using the following equation:

$$\text{Fish Height} = \frac{\text{1st bottom return col \# } * C_{\text{water}}}{\text{Maximum \# columns } * 2}$$

Unless changed by the user, SIDESCAN automatically uses the average fish height based equally on the returns from each transducer. The berm and buoy image following water column removal is shown in Figure 7.

The slant range error (shown in Figure 8) can be solved by means of the distance, rate, and time relationship, and the Pythagorean theorem. First, the height of the fish above the bottom is determined. Next, the slant range distance of each data point from 0 to 883 on each channel is computed with the formula Distance = Rate * Time. Rate is the speed of sound in water (assumed to be 1500 m/s) and time is the one way travel time of a single pulse in the water (transmit period). The true distance is then calculated by using the Pythagorean Theorem; the slant range is the longest leg of the triangle and the fish height is the shortest. SIDESCAN then displays the pixel using the true distance, rather than the slant distance, from the centerline. This procedure assumes that the sea floor is a flat horizontal plane surface. While this is hardly ever truly the case, the depth in the Chesapeake Bay varies only slightly over a few hundred meters of lateral distance, making the approximation a valid one.

Following slant range correction, the anamorphic correction adjusts the aspect ratio across and along track. In most cases the along track dimension is compressed, and must be stretched out by repeating pixel rows. The true distance of each pixel in the across track dimension has already been computed during the slant range portion of the program. Based on the vessel's speed, the distance traveled during each pulse can be found by multiplying the vessel speed by the round trip transmit period. Then, the number of times to display each row of pixels is computed by dividing the speed interval (in m) by the across track pixel size (in m/pixel). The computer keeps track of the number of rows to repeat or skip, depending on the vessel speed. Obviously, if the vessel travels quickly, the number of rows to repeat increases. The opposite is true for a slowly moving vessel. The resultant image contains pixels which represent the same amount of real distance in the across and along track dimensions. At the same time, the algorithm also corrects for small speed deviations. These geometric corrections allow the user to view the bottom as it would look to someone peering over the side of the vessel [*Chavez*, 1986; *Searle*, 1990]. They can be seen applied to the berm and buoy image in Figure 9.

A few factors leading to further geometric errors have been neglected due to the short range and high frequency of the EG&G Model 272-TD. These factors, including ray bending caused by sound velocity gradients and towfish instabilities, cause major problems for long range imaging systems such as GLORIA. The small scale nature of this study reduces these errors so that correction is not warranted [*Cobra et al.*, 1992; *Searle*, 1990; *Miller et al.*, 1991].

3.3.2. Radiometric Corrections

As one can see from Figure 10, the average returned energy from the file containing the berm and buoy (8NOVS1) clearly drops off with distance despite the automatic towfish correction (TVG). This backscatter drop off can also be seen in Figure 6. The energy increases rapidly near the towfish when the bottom is first reached and then gradually decreases until the end of the swath width is reached. Correcting the across track signal strength inconsistencies are also relatively simple. First, SIDESCAN reads every record in a chosen file and computes the average digital number for each across track column, excluding the water returns. These averages are stored for future use. When the user wishes to display the data in radiometrically corrected mode, the digital number for each pixel is adjusted to compensate for over or under ensonification. Digital numbers are altered according to the following empirical formula (using the value of 32 as a target reference strength because it is half of the possible 64 DN range):

$$DN_{(i,j)} = \frac{DNold_{(i,j)} * 32}{DNavg_{(j)}}$$

The across track variation in pixel shading is removed by dividing the averaged pixel strength into the actual pixel strength at the same range. The equation forces columns with DN averages above 32 (generally those near the centerline) to be scaled down and columns with DN averages below 32 (generally those at extreme ranges) to be scaled up. It forces uniformity in the image color across track without blending colors together [*Chavez*, 1986; *Searle et al.*, 1990]. The effect this has on the across track average is shown in Figure 10 and the effect this has on the image is shown in Figure 11. *Miller et al.* [1991] used the same power drop off correction procedure with a function called PRDROP. Figure 12 shows the steps by which SIDESCAN corrects all of the side-scan errors.

3.3.3. Bottom Tracking Problems

In one case, across track distortion resulted due to miscalculation of the fish height. From the deep channel region, Figure 13 shows patches of shifted pixels contaminating the sonograph. Both the across track DN average vs. distance from centerline graph (Figure 14) and the computed fish height graph vs. position in the file (Figure 15) revealed significant differences between the port and starboard transducers throughout the entire file. This problem arose during a data run (31MAR94) over the deep channel region of the mid Chesapeake Bay. For this data, when the starboard channel was used for fish height computations, the curve was extremely scattered, while when the port channel was used, the fish height plot was very smooth. The fish height plot is dependent upon the chosen DN to represent the strength of the bottom (bottom value) and the individual across track DN values. Thus, fish height is also dependent upon the performance of the transducer. The most likely explanation for this aberration is that the starboard transducer underwent some frequency variation, while the port transducer operated at a constant frequency. Figure 16 shows the presence of an abnormal amount of noise in the starboard transducer water column. A DN in the water column which exceeds the chosen bottom value will produce a very shallow fish height. To alleviate this problem, which causes errors in the across track pixel shift table creation because of the abnormal fish heights, the user is permitted to choose which channel, or an average of both, to use for bottom tracking. In this case, choosing the port channel for bottom tracking fixed the problem. Figure 17 shows no pixel shifting.

3.4. Ground Registration

Ground registration, or correlating image locations with coordinates, is useful for several reasons. To the user displaying raw images and mosaics, a ground registered image allows the true speed of the towfish over ground to be used, eliminating any along track compression or expansion due to currents. Figure 18 illustrates the speed through water vs. speed over ground error. One sonograph was displayed using the speed through water and the other using the speed over ground. A 1 knot current was pushing the towfish at the time. Thus, the speed through water, being less than the speed over ground, is underestimating the bottom area imaged in the along track dimension by 1 knot, producing along track compression. Because towfish speeds are usually 5-6 knots, a 1 knot current can produce a 20% difference between speed through water and speed over ground. A ground registered image also allows the user to acquire the location in universal transverse mercator (UTM) and latitude and longitude coordinates of any pixel on an image. The Naval applications of this feature are obvious. With this display software, mines or wreckage could be easily identified and assigned a latitude and longitude. These coordinates could be quickly disseminated to mine disposal or salvage units, which would aid in decreasing response times.

Ground registering is perhaps the most important addition to SIDESCAN. Side-scan data and GPS time and position data from the towing vessel are the only necessary components. The side-scan unit has an internal clock, which starts at 0:00 when the unit is turned on. Assuming a second of side-scan time is the same as a second of GPS time, once the offset is known, the times can be altered on the side-scan records. Then, by simultaneously reading the side-scan records and GPS times, matches are found. Once a match is found, the GPS UTM coordinates and headings are written to blank data blocks on the side-scan records. The coordinates of any feature to the side of the centerline can be found by using the heading and simple geometry. The distance offset between the location of the GPS unit and the location of the towfish (based on towing cable length of 25 m) is also applied. A flow chart (Figure 19) demonstrates how SIDESCAN ground registers side-scan data.

3.5. Image Enhancement

Once a side-scan sonograph is fully rectified, it may be analyzed using standard image analysis software, such as that created by *Guth* [1991]. However, first the side-scan data must be written to image files. An option in SIDESCAN allows the user to copy side-scan data to a raster image file, stored by rows from the upper left corner of the image. SIDESCAN creates the image file (.BN1 suffix) and an index text file which contains the dimensions of the image (.IDX suffix). Finally, the coordinates of the corners of the image are written to a text file (.XY suffix) so the outlines may be plotted. The outlines of fully corrected side-scan data which has been written to image files are shown in Figure 20. The image files can then be graphically selected and enhanced using image processing routines.

Side-scan data, like other remote sensing data, contains a certain amount of both Gaussian and non-Gaussian speckle noise. Figure 21, an image of the wreckage of a barge, shows how speckle noise pervades side-scan images. Filtering is an image enhancement technique which alters the overall texture of an image. Smoothing filters work by reassigning the pixel digital numbers based on an equally weighted average of the points around them. The size of the filter determines the amount of smoothing. For example, a simple 3 x 3 averaging filter averages a 3 x 3 box of nine points and places the result in the middle of the box. The process continues throughout the entire image. As the size of the filter increases, so does the number of points which are averaged, and with it the blurring of the image. Thus, a dilemma exists: the addition of more filtering removes speckle noise, but it also degrades the resolution of the image. The 3 x 3 averaging filter produced the best results for the side-scan image files. The speckle noise was lessened considerably without overly degrading the detail of the image. A 3 x 3 filter applied to Figure 21 results in Figure 22. Although more speckle noise was removed with the 5 x 5 (Figure 23) and 7 x 7 filters, the negative aspect of the resolution degradation outweighed the positive aspect of the speckle noise removal. After the averaging, a contrast stretch was automatically applied to restore the range of grey scales to the image.

Other filters can be used to modify a side-scan image. Unlike smoothing filters, median filters merely sort the data points, instead of averaging them. This method helps to preserve sharp transitions while also removing speckle noise. Edge filters are useful when applied to areas where anomalous return enhancement is desired. Using an edge filter on Figure 21 resulted in Figure 24. The anomalous returns from the wreck made it stand out from the background [*Bangham*, 1990].

3.6. Digital Mosaicking

The final stage in digital side-scan processing displays side-scan data on a UTM projection based on the actual ground coordinates of each data point [see *Snyder*, 1987, for information on map projections]. While straight passes and turns may not be readily evident with normal side-scan display software, they are readily apparent when plotted. Figure 25, a registered and corrected image file of a 180° turn over the Thomas Point oyster bar, looks much different when the individual data points are plotted on a projection (Figure 26). Standard military UTM grid lines, plotted in white, show the location of the mosaic. Mosaicking, or combining several side-scan data files onto a single projection, is an extremely powerful and useful technique. It allows the scientist or tactician to view a large area of the sea floor at a single glance. Large scale geologic features such as submarine ridges or canyons can be easily identified. Naval personnel will be able not only to identify mines but also to accurately determine their locations or positions relative to other geographic features. Combining image segments with similar look angles yields mosaics that show features all with congruent shadow patterns. In Figure 27, a mosaic with a common look angle from the mid Chesapeake Bay area, large scour or trawl marks can be followed over long distances. This mosaic, and all subsequent mosaics, are displayed rotated 90°, with north to the left side of the page. Features can be identified even more accurately by comparing mosaics of the same area and different look angles. The presence or absence of acoustic shadows will delineate the differences between bathymetry induced backscatter variation or sediment induced backscatter variation. Most importantly, other registered data sets including bathymetric data can be overlaid accurately with image processing software [*Prior et al.*, 1979; *Chavez et al.*, 1986; *Danforth et al.*, 1991; *Guth*, 1991].

The digital mosaicking process begins by querying the user about the desired location of the upper left hand corner of the finished mosaic. The computer then sets up a one meter by one meter grid in UTM coordinates. The overall grid size is set by a constant. Due to computer memory limitations, the square grid is set to a default value of 1800 m by 1800 m. The mosaic size could be increased by writing the mosaic to the hard disk instead of to memory, although this would slow the program considerably. Next, the user selects the channel and specific image to be used for the first component of the mosaic. By allowing the user to select the channel, look angle specific mosaics can be created. For users wishing to maximize coverage, both channels may be selected. The first individual record is then read and the towfish height determined. SIDESCAN then cycles through the 884 values comprising the desired channel of data. The true distance of the data point from the centerline is computed, and, based on the heading of the vessel for that record, the true x and y UTM coordinates are computed. The radiometric correction is applied to the DN of the data point, and, if the point is located within the preselected mosaic area, it is plotted on the screen and written to memory. This process is repeated until the entire side-scan file is read, and then the user is prompted for another side-scan data file. Once the user is satisfied with the overall composition of the mosaic, the mosaic values are written to an image file, which can then be analyzed with standard image display software. The resulting image displays the side-scan data fully corrected for geometric and radiometric errors and properly fitted to ground coordinates.

The only limitation to this technique is the precision of the navigation data. Since data points must be precisely positioned for data to overlap perfectly, coherent overlapping mosaics are almost impossible to generate. To account for the position of the towfish relative to the GPS receiver, a constant was subtracted, based on ship heading, to the centerline UTM coordinates. Thus, fluctuations in towfish location are unaccounted for. This limitation alone would reduce data position accuracy by at least 2-3 m, which makes mosaicking on a 1 m by 1 m grid unreliable. Position accuracy can be assessed by comparing feature locations on different images. For example, on the 23MAR94 data run, between Tolly and Thomas Points, a bend in a submarine cable could be clearly discerned on both the southward and northward passes. The UTM coordinates differed by less than 1 m in the x direction but over 30 m in the y direction. *Kuwahara and*

Poeckert [1989] encountered similar overlap problems with their Klein side-scan system and attributed it to "unknown and uncorrectable errors" relating to towfish instability. *Luyendyk et al.* [1983], when digitally mosaicking side-scan images from the Anacapa Passage, also found that, due to imprecise navigation, common features were displaced more than 150 m on different tracks. To solve this problem, they stressed the need for a continuous knowledge of towfish dynamics.

SIDESCAN resolves data conflicts by overwriting the mosaic data. The most recently added data segment replaces the older data written. The most feasible solution to this problem lies with the user. For the most easily readable mosaic, the user should select data segments which do not overlap and share the same general look angle. Figure 27 is an example of a mosaic constructed using well chosen data files and look angles. Figure 28 shows outlines of the created mosaics; table 4 lists the basic characteristics of these mosaics. One final feature of this portion of SIDESCAN allows the user to merge two or more mosaics from the same area into a single mosaic.

4. Characteristics of the mid Chesapeake Bay

4.1. Bathymetry

Nearly 300 km long and from 8 to 48 km in width, the Chesapeake Bay is the largest estuary in the United States. The Bay formed during and after the last glaciation, when melting glaciers caused a 100 m rise in sea level and a flooding of the Susquehanna River. The general bathymetry of the bay reflects this process. The final remnant of the old Susquehanna River is a deep (about 30 m) trough, or thalweg, in the eastern portion of the bay. The bottom rises up from the thalweg to produce an average water depth of 8 m [*Cuthbertson et al.*, 1989].

To study the dependence of the side-scan image upon bottom bathymetry, a bathymetric digital elevation model (DEM) (Figure 29) was created of the study area using MICRODEM [*Guth*, 1991]. A microcomputer aboard the research vessel logs GPS positions and Odom fathometer depth readings whenever the research vessel departs Annapolis on a scientific mission. To create the DEM, the position and depth files were merged into one file. To remove erroneous readings, data points were excluded if they differed from the previous value by 2.5 feet (0.762 m). Strings of anomalous depths were removed manually; most of these were from a single day's operation. Because the research vessel did not cover every point of the study area, patches lacking data were filled in by interpolating between the existing points using a 20 m grid. This process created a comprehensive illustration of the mid Chesapeake Bay's bathymetry. The finished DEM can be used to discern bathymetric changes of 0.03 m (0.1 feet) in elevation over 20 m in horizontal distance.

The interpolated DEM of the study area revealed that the Bay is shallow (6-9 m of depth) near the western edge of the area, with the water depth reaching a maximum of 41.6 m near the eastern edge of the study area. The bottom gently drops off from the west to the east (slope of 0.135°, 6.48 m over 2.75 km). The slope increases to 0.919°, or 13.8 m over 0.86 km, in the eastern 1 km of the study area. The bay then slopes up to the Eastern shore from the deep axial channel (2.06°, or 6.04 m over 168 m), producing a steep trough compared to the rest of the study area. The bathymetry is generally consistent along the north-south axis. Over the mid Chesapeake Bay region, the north-south slope is only 0.055°, or 4.12 m over 4.295 km. In the area of the thalweg, the north-south slope is 0.171°, or 10.5 m over 3.519 km. Water depth increases to the south. The results from the bathymetric study are consistent with the fact that the Chesapeake Bay was formed by the flooding of the Susquehanna riverbed, which flowed from the north to the south.

4.2. Sediment Types

The surficial sediments of the Maryland portion of the Chesapeake Bay can be divided into three categories. From largest to smallest grain size, they are sand, silt, and clay. The coarsest type of common sediment, gravel, was excluded from consideration because the majority of gravel sediments were found as lag deposits, which are not naturally occurring phenomena. Of all of the sediment samples collected by *Kerhin et al.* [1988] in Maryland portions of the Chesapeake Bay, nearly 75% fell into the sand (57%) and silty clay (17.9%) categories. Only a few samples were classified as purely clay or silt. Figure 30 is a tertiary diagram of the sediment samples *Kerhin et al.* collected in the Maryland portion of the Chesapeake Bay. Sediment sizes tend to increase as one moves southward towards the mouth of the Bay. *Kerhin et al.* used a Rapid Sediment Analyzer (RSA) and Coulter Counter Model TAII to determine sediment classification.

Generally, sands are located near the shorelines of the Bay, while silty clays predominate in the center. Sandy sedimentary environments are characterized by high wave and tidal energy. Conversely, areas of sluggish water movement yield finer grained sediments. A relationship also exists between water depth and sediment type, with sediment size increasing in fineness with an increase in depth.

The main sources of Chesapeake Bay sediment are the Susquehanna River and shoreline erosion. Silty clay, carried by the Susquehanna, is deposited in the maximum turbidity zone, where the fresh water of the river meets the salt water of the Atlantic Ocean. Near the area where this side-scan study was done, sandy sediments are formed by the erosion of Kent Island Pleistocene sediments. The bathymetry of the main axis of the Chesapeake Bay near the Chesapeake Bay Bridge is rather flat due to the extremely high rate of silty clay accumulation (17.8 mm/yr, compared to a rate of 0.7 mm/yr farther south, near Annapolis) [*Kerhin et al.*, 1988]. Due to the large sampling interval (1 km by

1 km grid) *Kerhin et al.* used in their research, their maps were not used as ground truth for side-scan interpretation [*Ryan*, 1953; *Kerhin et al.*, 1988; *Cuthbertson*, 1989).

The Tolly Point shoal, labeled as N.O.B. (natural oyster bar) 6-6 by the Maryland Department of Natural Resources, extends from 0.75 miles due east of the Annapolis city dock down the Severn river to about 1.25 miles east of Tolly Point. The bar encompasses a total of 1850 acres and ranges in depth from less than 1.83 m (6 feet) to over 5.49 m (18 feet). Just over a mile south of the terminus of the Tolly Point shoal lies a small (154 acre) natural oyster bar, Thomas Point shoal, designated as N.O.B. 6-15. It is located a mile east of the coast and 1000 yards north of the Thomas Point lighthouse. The water depths over the shoal range from just under 3.66 m (12 feet) to over 5.49 m (18 feet). Figure 31 shows the outlines of the Tolly and Thomas Point natural oyster bars in the study area [*Department of Natural Resources, State of Maryland*, 1961].

To validate, or ground-truth, sediment type interpretations, the actual nature of the bottom must be discerned. A variety of methods may be employed to determine the nature of the bottom at any particular point, including: photography, visual inspection (divers), core sampling, surface grab sampling, or historical data [*Menzie et al.*, 1982; *Gardner et al.*, 1991].

Over 50 samples of the surface sediments of the Chesapeake Bay bottom were collected using an orange peel grab. Locations of mud and oysters are plotted in Figure 32. The mud samples were analyzed for composition by weight and size using a GALAI CIS-100 particle size analyzer, provided by the Marine Sciences Division of the National Oceanic and Atmospheric Association. Statistical results from this analysis are given in Table 5. The statistics were not used because a dispersant was not used on the samples before the analysis. Thus, size data was skewed depending on the amount of mud flocculation, or particle clumping. Because different samples may have flocculated more than others, even general trends cannot reliably be drawn. Also, because oyster shells were too large to analyze with the size counter, samples from the oyster bar do not reflect the true sediment composition. Plotted on a tertiary diagram (Figure 33) and compared to *Kerhin et al.*'s results (Figure 30), the faulty method is obvious. The majority of samples plotted were silts or sandy silts, instead of the expected sands or silty clays. Ground truthing based on either mud or oyster samples correlated very closely with side-scan records, however.

5. Sonograph/Mosaic Interpretations

5.1. Large Scale Bathymetric Features

Bathymetric data is critical in side-scan analysis as a method of distinguishing returns caused by bathymetry or sediment type. For example, a particularly strong feature along the edge of a side-scan image could either represent a slope inclined towards the towfish or the edge of a rocky outcrop. Identification is especially difficult when shadows cannot be seen. With bathymetric data overlaid on a side-scan image, the nature of the returns is much easier to interpret. Figure 35 is a northeast look angle mosaic overlaid with 2 foot contours which shows the flatness of the mid Chesapeake Bay [*Searle et al.*, 1990; *Talukdar and Tyce*, 1990].

Correlations between the bathymetric data and side-scan imagery are limited by the accuracy of the DEM. Considering the smoothness of the Chesapeake Bay bottom in general, only a few locations have yielded good correlations between elevation changes and side-scan data.

The first of two such notable areas is the southern edge of the Tolly Point oyster bar. Here, the depth changes from 5.5 m to 9.1 m over 35 m. The maximum slope associated with this steep drop-off is 5.97°. This slope, extremely steep compared to the rest of the bay, is caused by the transition from a built up oyster bar formed on rocky sediment to a flat, muddy plain to the south. The transition can also be easily seen through the side-scan data as a broad white band (Figure 36). This strong return is caused by the reflection of the sound energy back to the transducers. Most of the passes through this region have illuminated the slope in a perpendicular manner. Had the sonar been towed parallel to the slope instead of perpendicular to it, the slope would have been even more noticeable. An oblique view, created in MICRODEM, of the oyster bar intruding from the west is provided in Figure 37. The comparatively steep southern slope is easily seen.

In comparison, Thomas Point oyster bar, at its steepest point, was 1.55°, or a depth change of 2.60 m over 96 m. However, data collection was extremely limited due to depth constraints in the Thomas point region.

The Susquehanna River thalweg, located in the eastern portion of the DEM, also could be identified with the side-scan. In this case, the depth changed from 19 m to 33 m over 861 m (from west to east), producing a gradient of 0.919°. Side-scan data from this region (Figure 38) shows a series of north-south aligned striations as the depth increases down to the maximum. At this point, the image becomes dark, signifying a lack of returning energy, as the sound is absorbed in the deep muddy channel. Then, when the bottom begins to slope upward once again from the channel eastward to the eastern shore, the image brightens because of the more direct return of the sound energy. The alignment of the towfish with the axis of the channel also plays a part in the increased brightness. This slope is stronger than the western slope down into the channel, being 2.06°, or 6.04 m over 168 m. Once again, a MICRODEM oblique view helps in illustrating the relative slopes (Figure 39).

5.2. Sediment Types

When plotted as image files, corrected side-scan data files from featureless regions reveal many differences in return strength, indicating changes in sediment type. Although bottom samples did not reveal enough variation to classify different types of mud, the difference between oysters, mud, and sand is readily apparent simply through observation. Also, a Department of Natural Resources Natural Oyster Bar chart revealed the extent of some local oyster communities. Based on this information, correlations can be made with particular image brightnesses within the images.

Figure 40 shows the transition between oysters and mud at the north edge of the Thomas Point oyster bar. Oysters produce particularly strong reflectances because of the hardness of the individual oyster shells and the roughness of the oyster bar [*Dealteris*, 1988]. In comparison, Figure 41, collected by the 1993 YP Oceanography Summer Cruise in Delaware Bay, reveals an area of distinct sand ripples. The brightness of this bottom lies between the oysters and mud.

Histograms, plots of the percentage of DNs in a region vs. the DN, reveal the actual reflectance values associated with the sediment types. The statistics from histograms from all study regions and sediment are listed in Table 6. A comparison of mud histograms from all five study areas (Figure 42) reveals that the mean DN varied from 22.68 in the deep channel to 26.68 in the mid bay. The standard deviations varied from 3.32 to 5.69. The small standard deviations indicate that the DNs did not vary much; the mud is not mixed with much sand or oysters. In comparison, mean sand backscatter values ranged from 30.39 in the north Severn River to 31.51 in the Severn River mouth. The sand ripple image from the Delaware Bay yielded a mean DN of 30.56. The standard deviations of the sandy images exceeded those of the muddy images by about 2 DN, indicating an increased DN variability. Some mud mixed in with the sand would have produced a greater standard deviation. The sand histograms are plotted on Figure 43. The Thomas and Tolly Point oyster bars produced the highest reflectance values (mean DNs of 36.49 for Thomas and 38.44 for Tolly). However, they also exhibited the greatest standard deviations (5.38 for Thomas and 8.21 for Tolly). This indicates that mud and sand were mixed in with the oysters, increasing the range of DNs. Sediment grabs from Tolly Point oyster bar confirm that oysters are never found free of mud. The reflectance histograms for these two regions are shown in Figure 44.

With these values thus delineated, a DN index can be created for side-scan images. Return strength histograms can be classified quickly as one of the three pure sediment types or a mixture of two or more, depending on the number of peaks in the histogram. The higher the peak, the more predominant the particular sediment type. Figure 45 illustrates this breakdown. Two histograms are plotted for each sediment type. The transition from mud to sand occurs at a DN of about 27 and the transition from sand to oysters occurs at a DN of about 34. Thus, images may be roughly categorized by plotting the histogram of a region and matching the peaks with characteristic values.

A different way to analyze sediment backscatter data uses MICRODEM to perform a fast fourier transform (FFT) by row of three characteristic sediment images. Figure 46 shows the resulting three different power spectra. Clearly, differences can be discerned between the mud, sand, and oyster images. *Shaw and Smith* [1990] explore this method and several other statistical methods for analyzing geophysical data. MICRODEM can also plot semivariograms of side-scan data, showing the spatial correlation of the data. Figure 47 is a semivariogram of the same three sediment type images. It shows consistent variations for mud, sand, and oyster bottoms. *Curran* [1988] explains semivariograms in more detail.

5.3. Bedforms and Man Made Features

In addition to sediment types, the EG&G side-scan sonar also clearly revealed a variety of bottom features. Figure 48 summarizes the bottom features found and shows their locations in the study area.

The Severn River contained the greatest number of both man made and natural features. Buoys are easily resolved on sonographs for many reasons: hardness of the buoy and anchoring chain, wake created by the buoy in the presence of a current, and shadow zone behind the buoy. Figure 11 shows buoy G "11", its anchoring chain, and the shallow berm it marks. Two channel marker buoys, C "7" and N "6", are shown in Figure 49. The actual locations of the buoys are denoted by small (1-2 m) white dots. Dark regions represent areas of shadow or water turbulence. In addition to the buoys, small (5-7 m diameter) mounds were found in great concentration from the beginning of the Severn River shipping channei all the way south to the mouth of the Severn (shown at 75 m range in Figure 50 and 200 m range in Figure 51). Strong returns indicate not only height but also possibly a harder bottom type. Due to the unusual placement of these mounds in the Severn shipping channel, we suspect these mounds are dumpings from oystermen or other fishing vessels. A large (10-15 m diameter) mound, and a long (100-300 m) ridge were also discovered in the Severn River (Figure 51). Acoustic shadows denote feature heights of at least 1 m.

In between the Tolly and Thomas Point oyster bars, two submarine cables were revealed. An overview of the area immediately south of the Tolly Point oyster bar (Figure 52) shows two long cables; the first begins in the northwest and proceeds due southward, while the eastern cable angles toward the southwest. Figure 53 is a more detailed image of the crossing point of the two cables. A bend in the eastern cable indicates a possible break or rupture in the cable.

The mid Chesapeake Bay bottom is marked by a plethora of pock marks. Long, curving returns with no acoustic shadows also dominated this region. These long (100-200 m) features seen in Figure 54 may be furrows caused by bottom trawlers or dredgers. The lack of acoustic shadows and flatness of the DEM in this region signify the absence of notable bedforms.

Perhaps the most interesting feature discovered in the bay is the wreckage of a barge in the eastern portion of the bay near the axis of the deep channel. Sunk in about 15-18 m (50-60 feet) of water, it, along with its marking buoy, "WR87", can easily be discerned in Figure 55. Dark shadow returns denote significant height of the sunken barge. This image illustrates the practical applications of using SIDESCAN. The mosaic of the area shows the locations of the barge and buoy and their relative positions. Had this been a recently sunken ship or submarine, salvage crews could now be dispatched to a precise location. Figure 56 is a detailed image of the barge, showing the high resolution of the sonar. Two of three rectangular hatches can easily be observed.

5.4. Surface Influence

The final type of feature the EG&G Model 260-TH system can resolve are interferences at the surface. On a particularly windy day (1NOV93), bottom features from the Severn River channel were partially obscured by wave interference (Figure 57). Sonar pings striking the surface are normally specularly reflected away from the transducers. However, as Figure 57 shows, high waves can produce strong returns because of the direct bounce from the wave back to the transducer.

The mixing of air bubbles in the water column also results in a high backscatter energy. This happens often in the Chesapeake Bay as a result of passing speed boats. Wakes can be seen crossing side-scan images several minutes after the boat has passed.

The best example of this is Figure 58. On the port channel of Figure 58 is the wake produced by the YP. The YP had just completed a nearly 180° 100 m radius turn when the previous track line wake became visible.

These two examples prove that the side-scan files may not simply be pictures of the bottom. Waves and wake are only two of the things that can affect side-scan returns. The operator must remain alert to environmental conditions when collecting data so that some anomalies can be identified immediately.

6. Conclusions

6.1. Results

Using a microcomputer to post-process digital side-scan sonar images offers many advantages. SIDESCAN automatically corrects the various side-scan imaging errors and allows the user to display the raw data in a variety of configurations. SIDESCAN also allows the user to merge EG&G side-scan data with GPS position data to produce ground registered images. These images, when copied to standard image files, can be analyzed for sediment type or bottom features using many different techniques, including digital elevation contour overlay, fast fourier transform, or semivariogram [*Guth*, 1991]. SIDESCAN allows users to quickly and easily manipulate side-scan data.

A wealth of side-scan data was collected in the Severn River and mid Chesapeake Bay using the EG&G Model 260-TH side-scan sonar system in the 100 kHz mode. No documented side-scan studies have ever been done of these areas. Interpretation of the data using SIDESCAN yielded a great deal of information regarding the nature of the Chesapeake Bay floor. Three sediment types, mud, sand, and oysters, were identified. They could be discriminated through image inspection, histogram reflectances, and FFT or semivariogram of the power spectrum. The sonar also resolved a variety of bottom features, including mounds and ridges in the Severn River, sand ripples in the Delaware Bay, and submarine cables, a wreck, and trawl marks in the mid Chesapeake Bay.

The only major disadvantage to using SIDESCAN for image analysis is the lack of a real time capability. *Danforth et al.* [1991] have developed similar correction and digital mosaicking routines which operate in real time. *Hampshire* [1989], also operating in real time, improved quantitative geological interpretations through combination of side-scan imagery and sub bottom profiler data. The resulting system reduced much of the subjective analysis of side-scan imagery. By feeding the side-scan output data directly into a microcomputer onboard the survey vessel, and with modifications to the program, data could be displayed on a UTM projection as it was collected. Implementing these changes would require directly accessing the digital tape drive's SCSI interface, necessitating that most of the testing of the program be done aboard the YP.

6.2. Future Research

A future enhancement to SIDESCAN might be the ability to digitally classify sediment types automatically in the side-scan images. The Chesapeake Bay region would present many natural challenges to this method. Firstly, regions of moderate bathymetric changes would have to be taken into account. This includes not only the Tolly Point and deep channel regions, but also anywhere the side-scan data was affected by the bathymetry, such as by the mounds or ridges in the shipping channel region.

Alexandrou and Pantzartzis [1990] used neural nets to digitally classify seafloor "provinces." Different bottom types possess unique acoustic signatures. Their method, tested only through computer simulations, uses pattern recognition to classify the sediment in question. Using a slightly different approach, *Mitchell and Somers* [1989] extracted backscatter strength values from the sonar transducer voltages with an acoustic propagation model. Quantitative comparisons were then made based on the similarity of the side-scan data to historical backscatter data. *Pace and Gao* [1988] accurately identified seabed types 97% of the time using a computerized discrimination system also based on statistical comparisons. *Tamsett* [1993] also characterized and classified seabed data using a power spectra analysis method similar to that used by *Pace and Gao*. His process, however, was very slow. Using SeaMARC II side-scan data, *Reed and Hussong* [1989] developed computer software which quickly classifies textural data. Raw side-scan images are transformed into image maps showing sediment texture based on gray-level co-occurrence matrices (GLCM). Their technique not only allows for qualitative and quantitative analysis, but also the ability to distinguish between features with similar image DNs but different lithologies. The limitation of this technique is their flat bottom assumption.

Considering the present scarcity of side-scan data, opportunities to image unexplored ocean floors abound. High resolution side-scan sonars, coupled with useful post-processing computer routines, allow researchers to gain insights into the geologic and bathymetric character of coastal regions such as the Chesapeake Bay. The recent push to explore the 200 nm exclusive economic zone (EEZ) surrounding the United States is just one example of how our need for more complete knowledge of coastal seafloors is increasing. Perhaps if researchers continue to probe the bottom of the oceans, someday this last of our earth's frontiers will be finally surmounted.

Acknowledgments. I would like to thank my adviser, Professor Peter Guth, for sparking my interest in this topic and for providing dedicated support. I also extend thanks to those who have, in one way or another, made this project possible: B. Yoakum, the crew of YP686, E. Stengl, K. Sabel, K. Zepp, the Maryland DNR, the USNA. Educational Resources Center, the USNA Photo Lab, M. W. Gleeson, M. Bem, and the Oceanography Department faculty. Finally, I wish to thank my family, Peter, Louise, Amy, and Benny, for their unwavering support.

Table 1. Model 272-TD towfish specifications [*EG&G Marine Instruments*, 1990].

	STANDARD RESOLUTION	HIGH RESOLUTION
MODEL 272-TD TOWFISH	("100 kHz")	("500 kHz")
ELECTRO-ACOUSTIC		
Operating frequencies:	105 +/- 10 kHz	390 +/- 20 kHz
Pulse length:	0.1 msec	0.01 msec
Swath width:	25 m to 600 m	25 m to 600 m
Acoustic output:	228 dB ref 1 μPa at 1 m	228 dB ref 1 μPa at 1 m
Horizontal beam width:	1.2° (3 dB points)	0.5°
Vertical beam width:	50°, tilted down 20°	50°, tilted down 20°
TVG range:	60 dB to 220 ms	19 dB to 75 ms
MECHANICAL		
Maximum depth:	600 m (2000 ft)	
Weight (out of water):	25 kg (55 lb)	
Dimensions:5.38	140 cm long x 0.41 cm diameter x 61 cm diameter tail (55 in. x 4.5 in. x 24 in.)	

Table 2. Summary of raw EG&G data files collected.

File name	Size (KB)	General location	Track (°T)	Swath (m)
1NOVS1	4,500	Severn R. mouth	140	100
8NOVS1	4,496	Severn R. mouth	140	100
8NOVS2	4,500	Severn R. mouth	140	100
8NOVS3	4,500	Severn R. mouth	140	100
8NOVS4	2,700	Severn R. mouth	145	100
8NOVS5	2,700	Severn R. mouth	165	100
8NOVSOY0	4,500	N. Tolly Point	180	100
8NOVSOY1	3,600	mid Tolly Point	200	100
8NOVSOY2	3,240	S. Tolly Point	200	100
8NOVN1	3,060	south of Tolly	320	100
8NOVNOY1	3,600	S. Tolly Point	015	100
8NOVNOY2	2,160	mid Tolly Point	015	100
8NOVNOY3	3,240	mid Tolly Point	345	100
8NOVNOY4	3,240	N. Tolly Point	335	100
8NOVN2	4,500	Severn R. mouth	330	100
8NOVN3	4,500	Severn R. mouth	330	100
18OCTN1	3,058	mid Bay	040	200
18OCTN2	3,448	mid Bay	040	200
18OCTN3	4,109	mid Bay	040	200
18OCTN4	3,929	mid Bay	040	200
18OCTS1	2,705	mid Bay	220	200
18OCTS2	2,568	mid Bay	220	200
18OCTS3	2,098	mid Bay	220	200
18OCTS4	2,340	mid Bay	220	200
25OCTE1	3,591	mid Bay	130	200
25OCTE2	4,446	mid Bay	130	200
25OCTE3	3,729	mid Bay	130	200
25OCTW1	4,181	mid Bay	330	200
25OCTW2	4,273	mid Bay	330	200
25OCTW3	4,235	mid Bay	330	200
7FEBE1	1,800	E. Bay	270	200
7FEBS1	4,887	E. Bay	180	200
23MARSOY	4,680	Tolly Point	140	200
23MARS	4,500	south of Tolly	180	200
23MARTH	2,880	Thomas Point	180/000	200
23MARN1	3,960	south of Tolly	010	200
23MARNOY	3,600	Tolly Point	015	200
23MARN2	3,240	Severn R. mouth	330	200
31MARE	1,800	E. Bay	270	200
31MARW1	2,520	E. Bay	090	200
31MARW2	1,800	E. Bay	090	200
SUM93SAN	2,340	Delaware Bay	???	150
WRECK	864	E. Bay	???	100
MOUNDS	864	Severn R. mouth	???	075
MOUNDS2	864	Severn R. mouth	???	075

Table 3. Features of program SIDESCAN.

SIDESCAN code written by Guth

Display of DOS EG&G data file
- User selects rows/columns to skip to adjust aspect ratio
- Water column removal

Create subsets of large side-scan files
Copy portion of uncorrected image to image file
Plotting options
- Distribution of backscatter returns with distance
- Backscatter returns versus distance for individual records
- Fish height as a function of position in record

Image processing (MICRODEM)
- Digital elevation model creation and analysis
- Bathymetric contour overlay
- Statistical options

SIDESCAN code written by Linder

Display single or multiple EG&G files on single screen
- Can display in multiple columns or inverted
- Data automatically corrected for slant range, anamorphic, and speed variation distortions
- Option to apply radiometric corrections
- Copy corrected side-scan data to registered raster image file

Other options
- Ground register EG&G files
- Create mosaics of data files or merge existing mosaics
- Modify bottomvalue or change transducer used for bottom tracking during data display

Table 4. Fully corrected and ground registered side-scan mosaics.

File name	General location	Upper left UTM coordinates		Look direction
		x	y	
NCHANNEL	Severn R. mouth	372,500	4,315,500	All
ECHNL	Severn R. mouth	373,300	4,314,500	E
WCHNL	Severn R. mouth	373,300	4,314,500	W
NELOOK	mid Bay	376,800	4,312,000	NE
NWLOOK	mid Bay	376,800	4,312,000	NW
SELOOK	mid Bay	376,800	4,312,000	SE
SWLOOK	mid Bay	376,800	4,312,000	SW
NTOLLYE1	N. Tolly Point	374,800	4,312,700	E
NTOLLYE2	N. Tolly Point	374,800	4,312,700	E
NTOLLYW1	N. Tolly Point	374,800	4,312,700	W
NTOLLYW2	N. Tolly Point	374,800	4,312,700	W
STOLLY1	S. Tolly Point	375,000	4,310,900	All
STOLLY2	S. Tolly Point	375,000	4,310,900	All
THOMASE	Thomas Point	374,800	4,309,100	E
THOMASW	Thomas Point	374,800	4,309,100	W
WRECKN	E. Bay	378,400	4,311,400	N
WRECKS	E. Bay	378,400	4,311,400	S

Table 5. Sediment sample statistics.

Latitude (°N)	Longitude (°W)	#	Name	Sand (%)	Silt (%)	Clay (%)	Mean (Phi)	Std Dev (Phi)
38.9556	-76.4441	1	19APR93G	42.56	56.83	0.61	4.07	0.73
38.9503	-76.4380	2	29APR93A	00.00	92.39	7.61	5.73	1.60
38.9503	-76.4367	3	19APR93F	42.49	55.63	1.88	4.26	0.92
38.9478	-76.4342	4	29APR93B	45.15	50.88	3.97	4.81	1.70
38.9484	-76.4331	5	A	42.71	54.38	2 91	4.42	1.11
38.9460	-76.4318	6	29APR93C	00.96	93.10	5.94	5.63	1.50
38.9452	-76.4316	7	19APR93E	58.84	40.80	0.36	3.82	0.85
38.9415	-76.4327	8	15APR93C	45.47	50.35	4.18	4.89	1.43
38.9433	-76.4283	9	29APR93D	55.89	43.14	0.97	3.82	0.86
38.9515	-76.4173	10	1NOV93I	52.06	47.15	0.79	3.91	0.73
38.9470	-76.4222	11	B	35.81	59.93	4.25	3.90	0.34
38.9435	-76.4218	12	1NOV93D	36.91	60.92	2.17	4.36	1.09
38.9397	-76.4293	13	29APR93E	00.00	86.05	13.95	6.03	1.72
38.9395	-76.4232	14	1NOV93C	47.96	50.91	1.13	2.27	0.26
38.9374	-76.4286	15	19APR93C	00.00	68.52	31.48	7.90	0.76
38.9357	-76.4282	16	29APR93Q	00.00	76.44	23.56	5.71	1.59
38.9341	-76.4304	17	19APR93B	00.00	73.90	26.10	6.45	-0.71
38.9342	-76.4285	18	29APR93P	00.00	92.00	8.00	5.25	1.72
38.9327	-76.4287	19	29APR93O	48.02	50.77	1.21	4.05	0.96
38.9312	-76.4313	20	29APR93H	68.32	31.57	0.12	3.69	0.72
38.9305	-76.4315	21	15APR93A	30.13	63.47	6.41	5.23	1.96
38.9303	-76.4297	22	29APR93N	68.73	31.07	0.19	3.71	0.70
38.9283	-76.4305	23	12APR93A	20.29	77.46	2.24	3.69	0.71
38.9272	-76.4330	24	29APR93I	39.45	58.52	2.03	4.00	0.74
38.9268	-76.4321	25	19APR93A	56.72	43.06	0.22	3.67	0.40
38.9263	-76.4315	26	29APR93L	00.00	93.46	6.54	4.33	1.05
38.9247	-76.4335	27	29APR93J	00.00	70.24	29.76	6.84	0.50
38.9243	-76.4317	28	29APR93K	48.09	48.98	2.93	2.24	0.26
38.9225	-76.4302	29	12APR93C	65.65	33.62	0.73	3.66	0.78
38.9200	-76.4310	30	12APR93B	44.20	51.98	3.82	4.79	1.66
38.9451	-76.4101	31	C	61.21	36.05	2.74	3 93	1.05
38.9446	-76.4041	32	D	00.00	90.83	9.17	5.24	1.72
38.9442	-76.4025	33	1NOV93H	00.00	72.43	27.57	4.03	0.91
38.9387	-76.3935	34	1NOV93G	63.26	35.85	0.88	3.74	0.89
38.9390	-76.4093	35	1NOV93E	51.62	47.05	1.33	4.26	0.99
38.9335	-76.3993	36	1NOV93F	42.33	53.85	3.82	4.65	1.49
38.9288	-76.4113	37	1NOV93B	45.30	53.59	1.11	3.60	0.77
38.9212	-76.4010	38	1NOV93A	27.11	66.85	6.04	4.42	0.82
38.9258	-76.4251	39	5OCT93A	00.00	83.37	16.63	3.89	0.34
38.9246	-76.4239	40	5OCT93B	10.92	79.85	9.23	5.33	2.04
38.9235	-76.4220	41	5OCT93C	23.80	70.57	5.63	5.43	1.86
38.9225	-76.4206	42	5OCT93D	00.00	90.74	9.26	2.22	0 27
38.9224	-76.4198	43	5OCT93E	56.39	41.86	1.75	3.65	0.78

Table 6. Side-scan image histogram statistics.

Sediment	Source Region	Mean (DN)	Std Dev (DN)
Mud	Severn R. mouth	24.13	4.47
Mud	Tolly Point	25.17	3.32
Mud	Thomas Point	25.55	3.27
Mud	Mid Bay	26.68	5.69
Mud	Deep channel	22.68	4.22
Sand	Delaware Bay	30.56	4.40
Sand	N. Severn R.	30.39	7.74
Sand	S. Severn R.	31.51	6.11
Oysters	Tolly Point	38.44	8.21
Oysters	Thomas Point	36.49	5.38

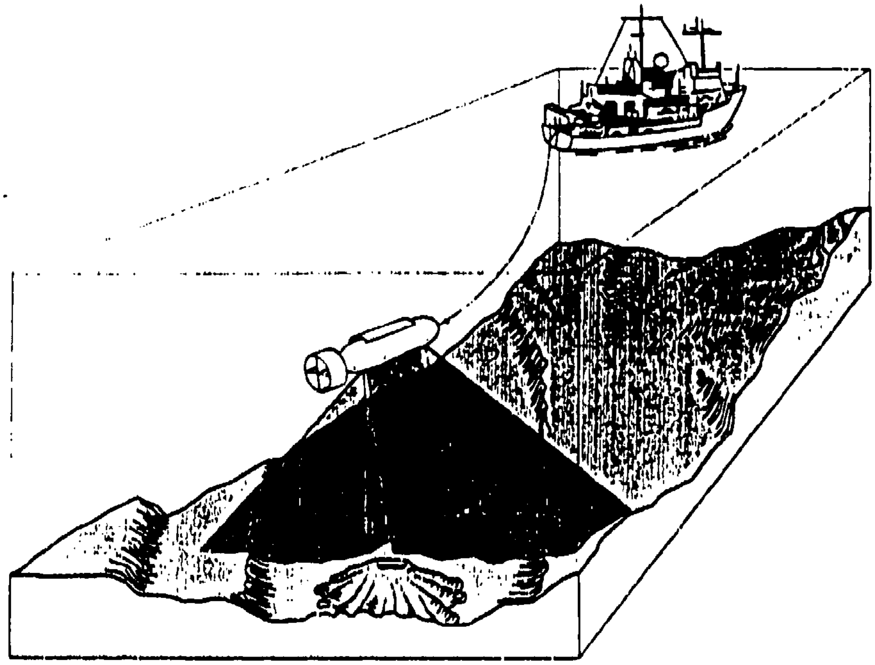


Figure 1. Side-scan sonar data collection.

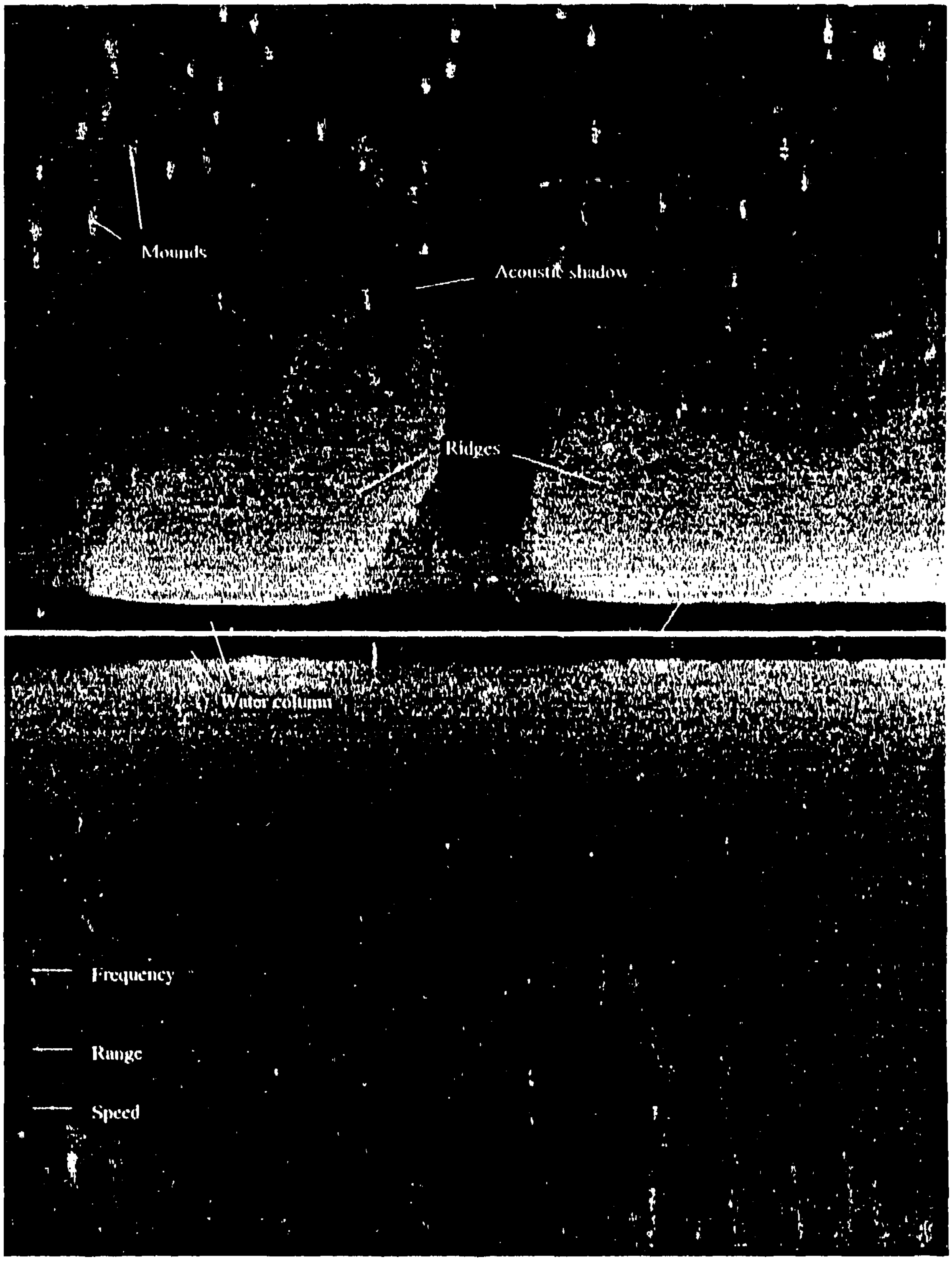


Figure 2. Uncorrected sonograph of the Severn River mouth

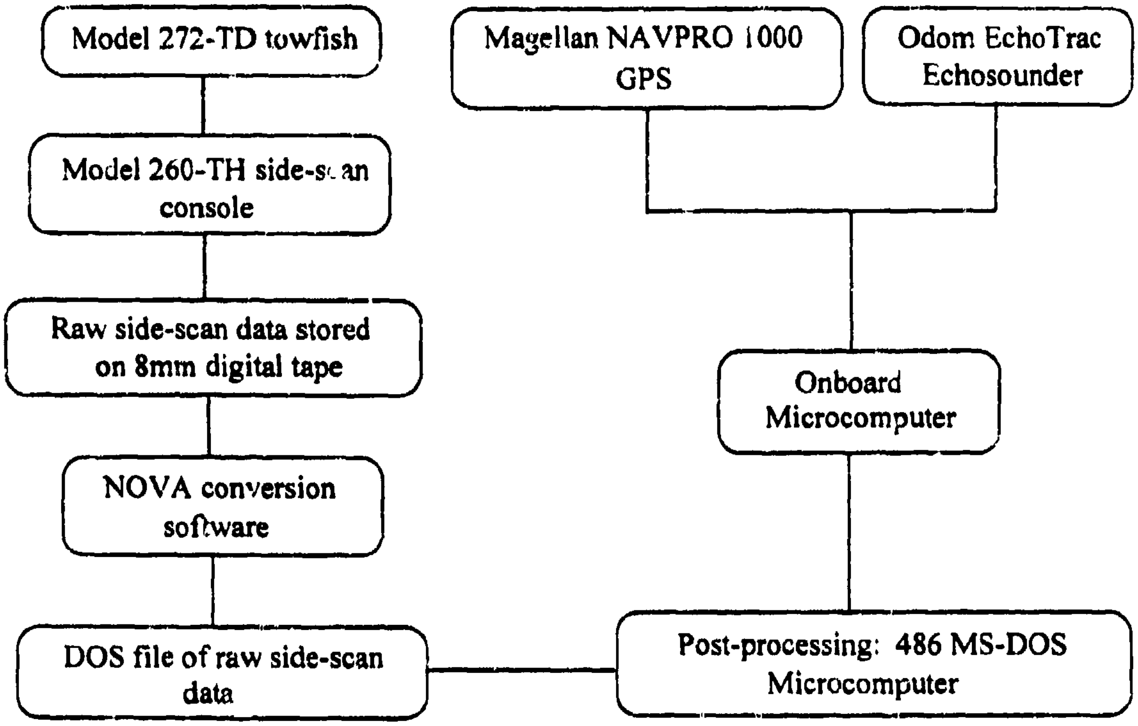

Model 272-TD towfish
Model 260-TH side-scan console
Raw side-scan data stored on 8mm digital tape
NOVA conversion software
DOS file of raw side-scan data
Magellan NAVPRO 1000 GPS
Odom EchoTrac Echosounder
Onboard Microcomputer
Post-processing: 486 MS-DOS Microcomputer

Figure 3. Relationships of hardware used.

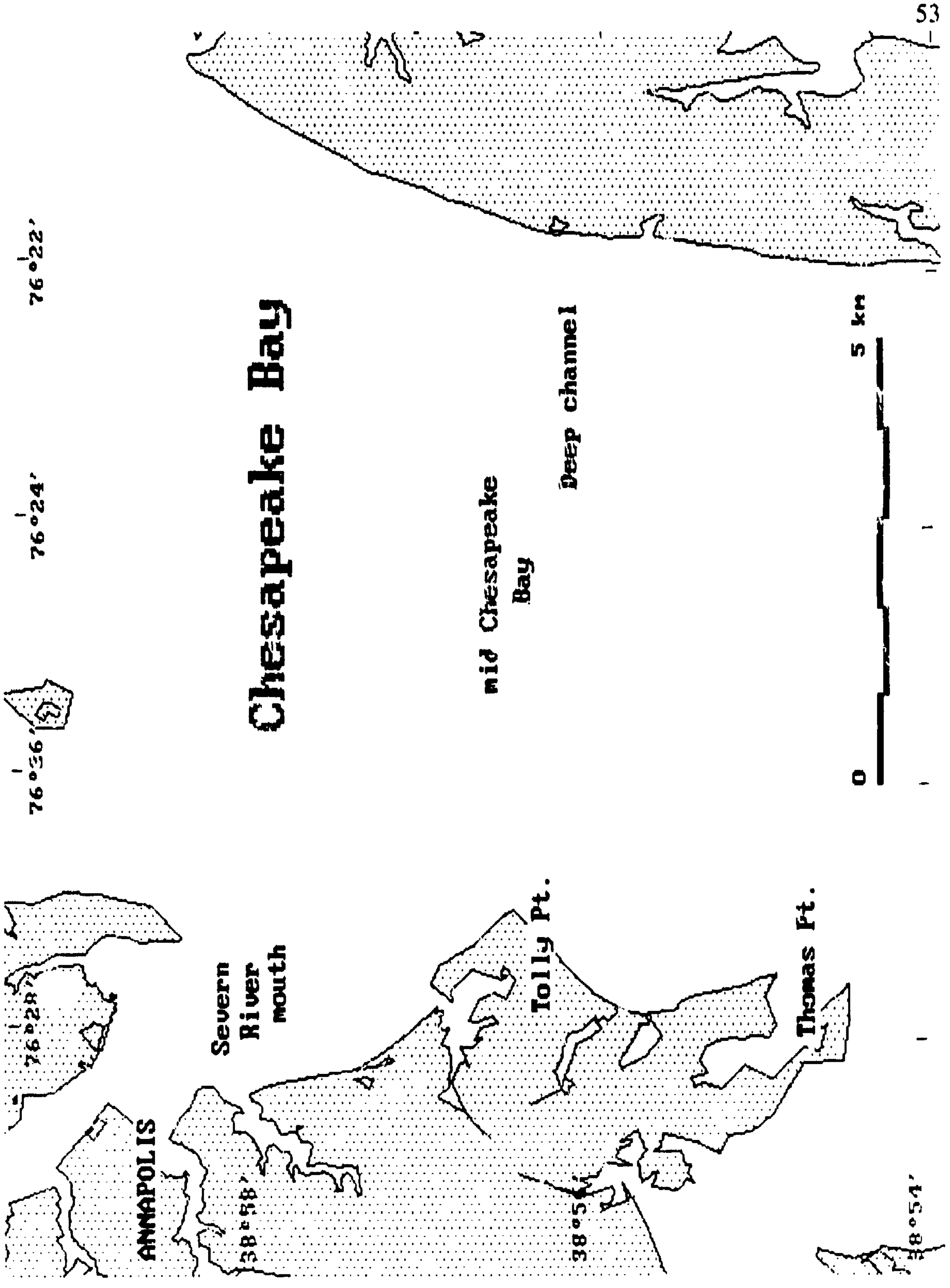


Figure 4. Study areas.

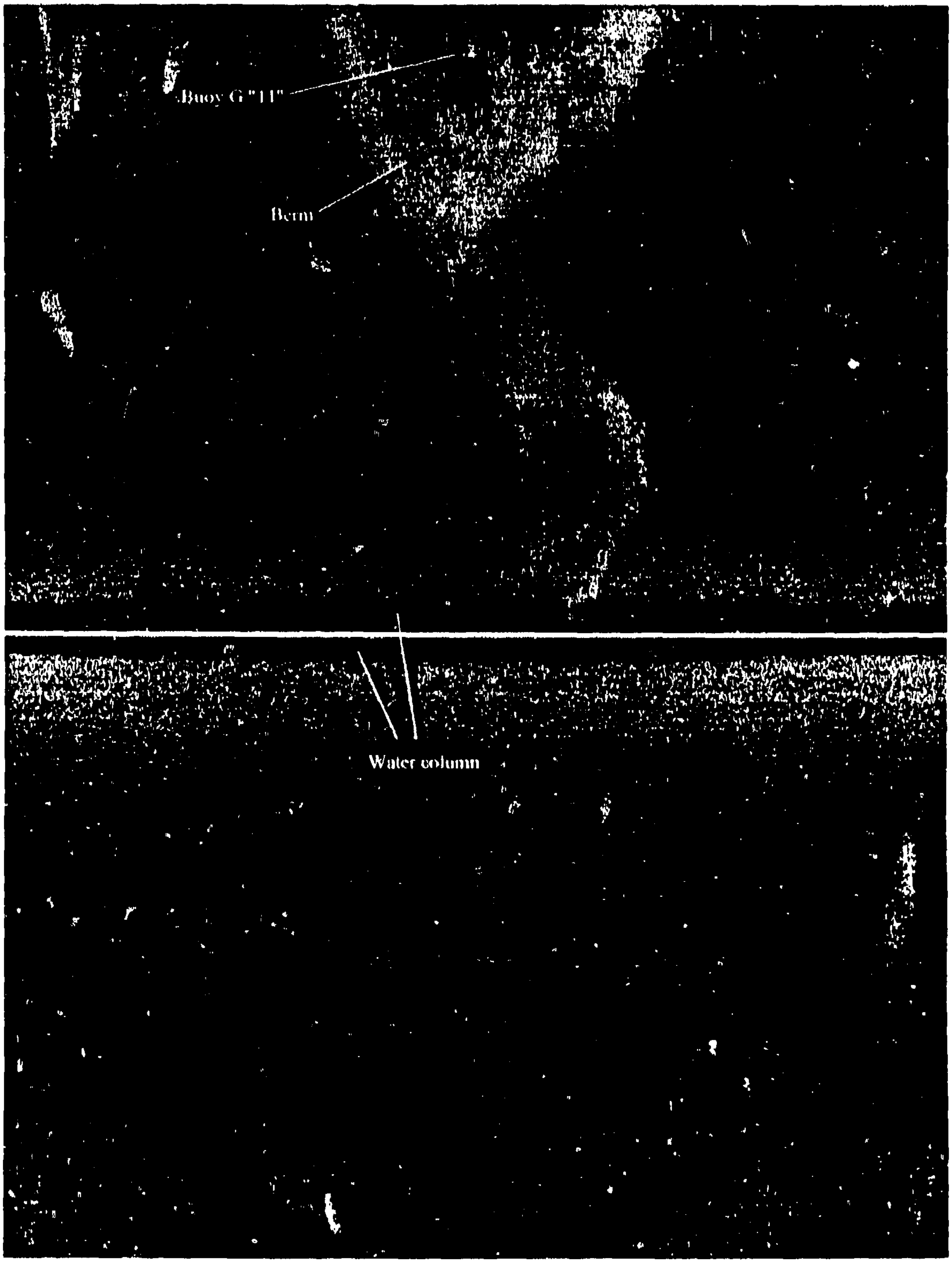


Figure 5. Uncorrected image of berm and buoy G "11" in the Severn River mouth.

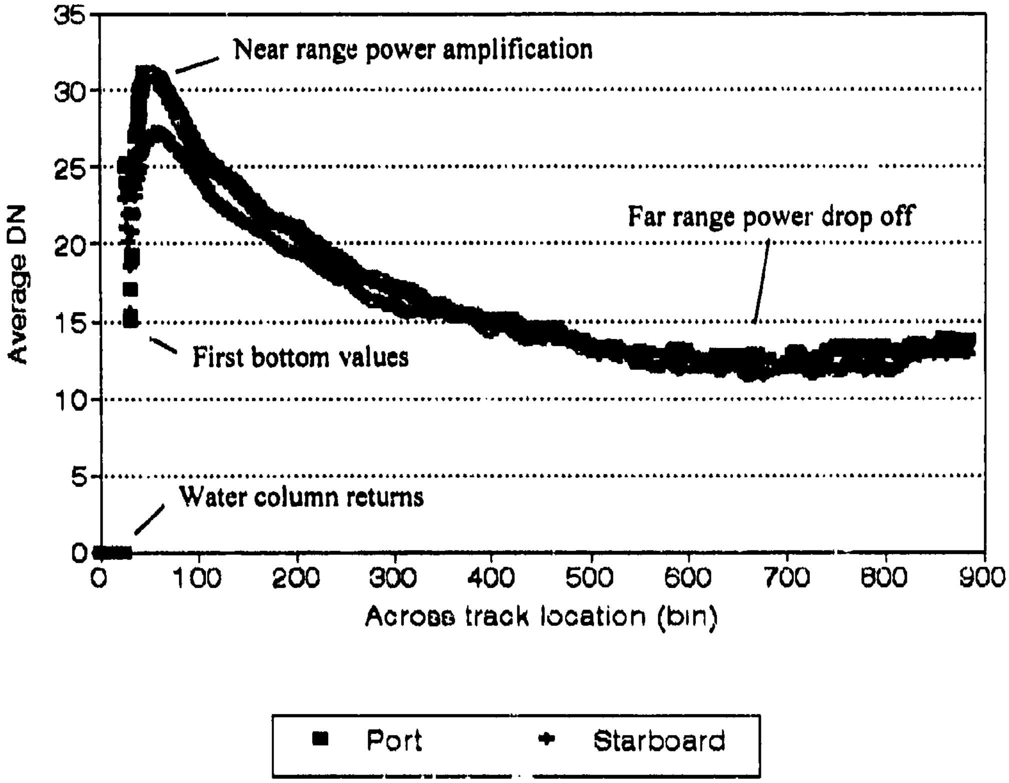


Figure 6. Average return strength vs. distance for a typical side-scan file from the mid Chesapeake Bay region.

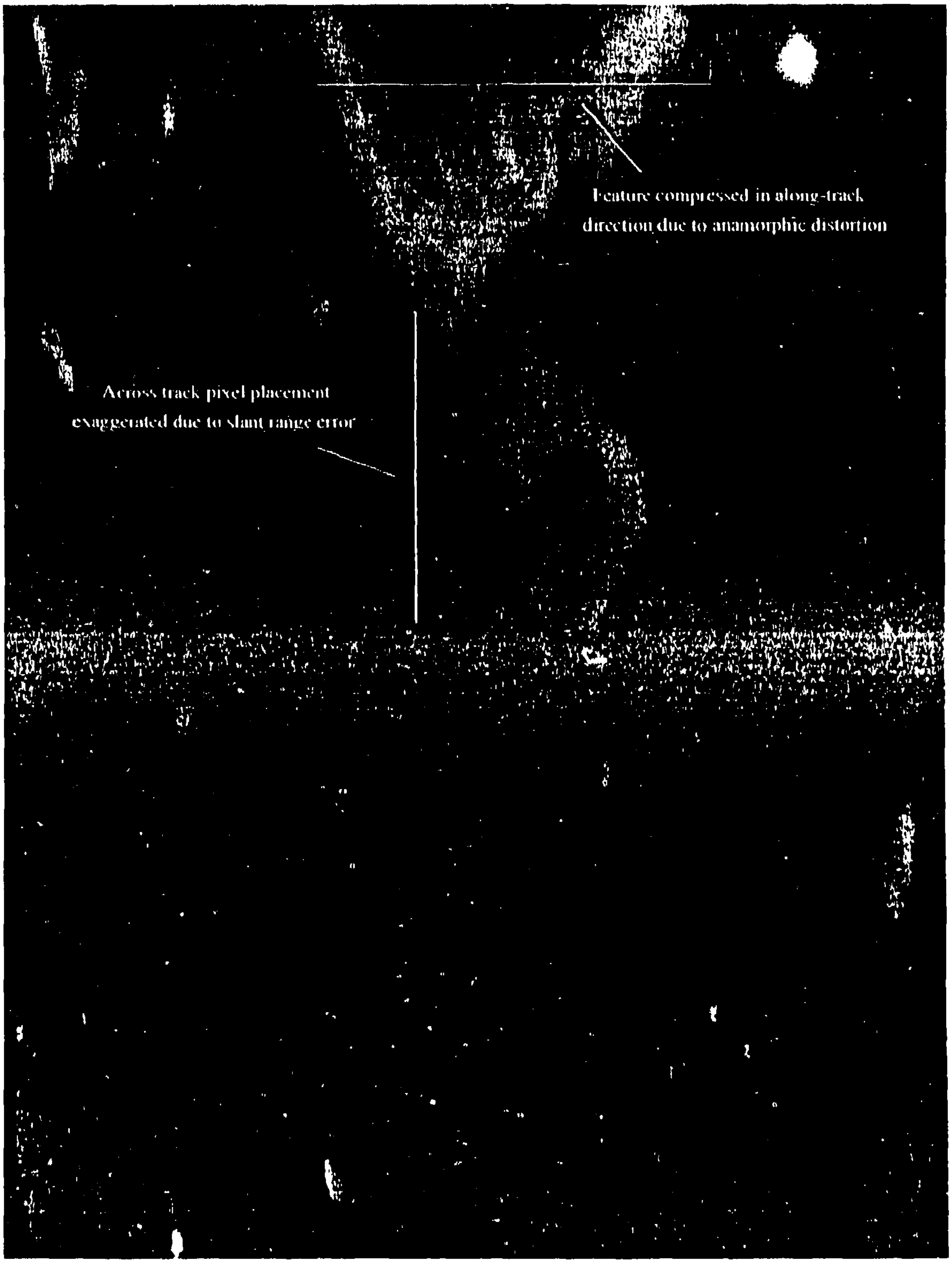
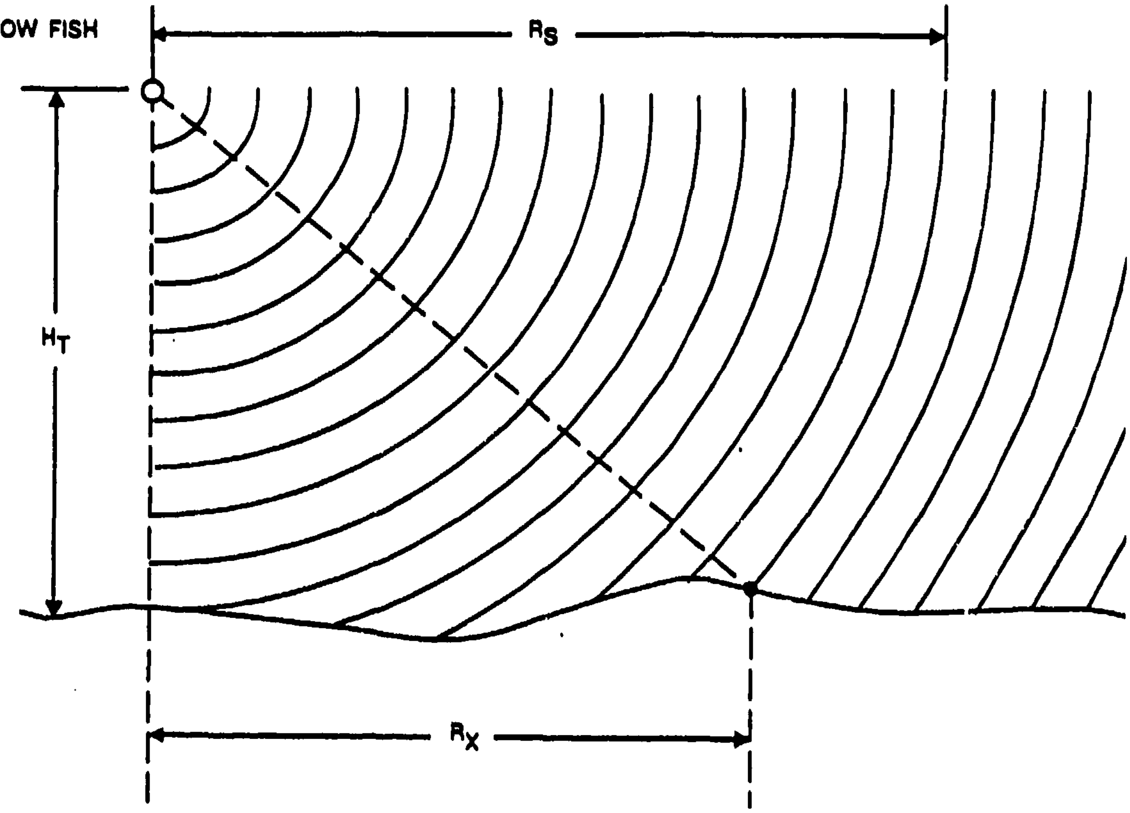

Feature compressed in along-track
direction due to anamorphic distortion
Across track pixel placement
exaggerated due to slant range error

Figure 7. Berm and buoy G "11" image with water column removed



$$R_X = \sqrt{R^2_S - H^2_T}$$

Figure 8. Slant range pixel placement error [*EG&G Marine Instruments*, 1991].

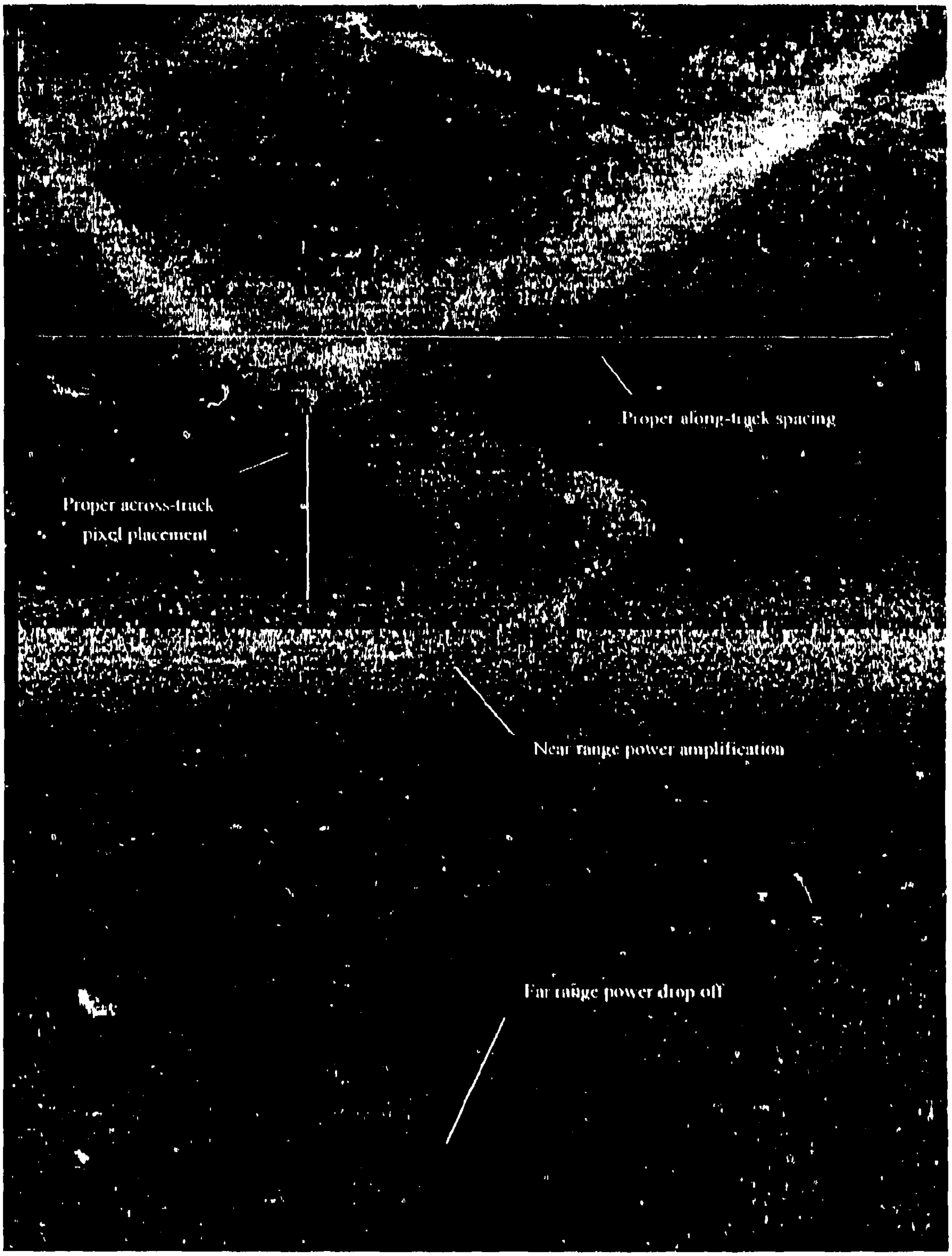

Proper along-track spacing
Proper across-track pixel placement
Near range power amplification
Far range power drop off

Figure 9. Geometrically corrected berm and buoy G "11" image

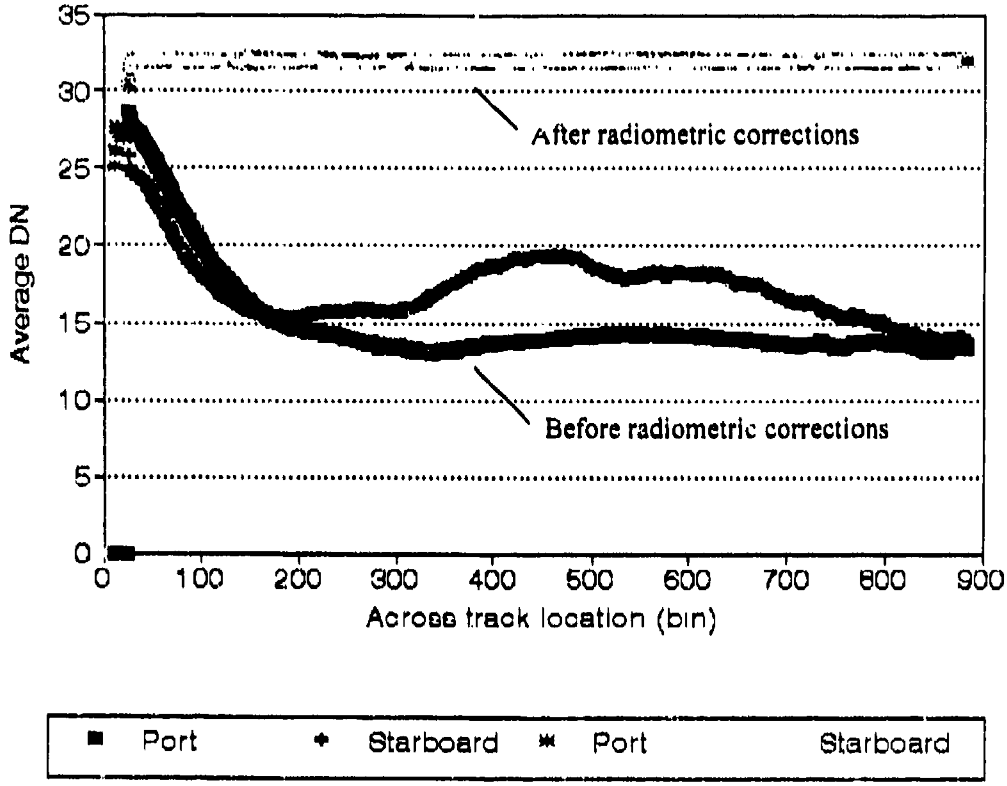


Figure 10. Average return strength vs. distance for 8NOVS1 (which contains the berm and buoy G "11" image) before and after radiometric corrections.

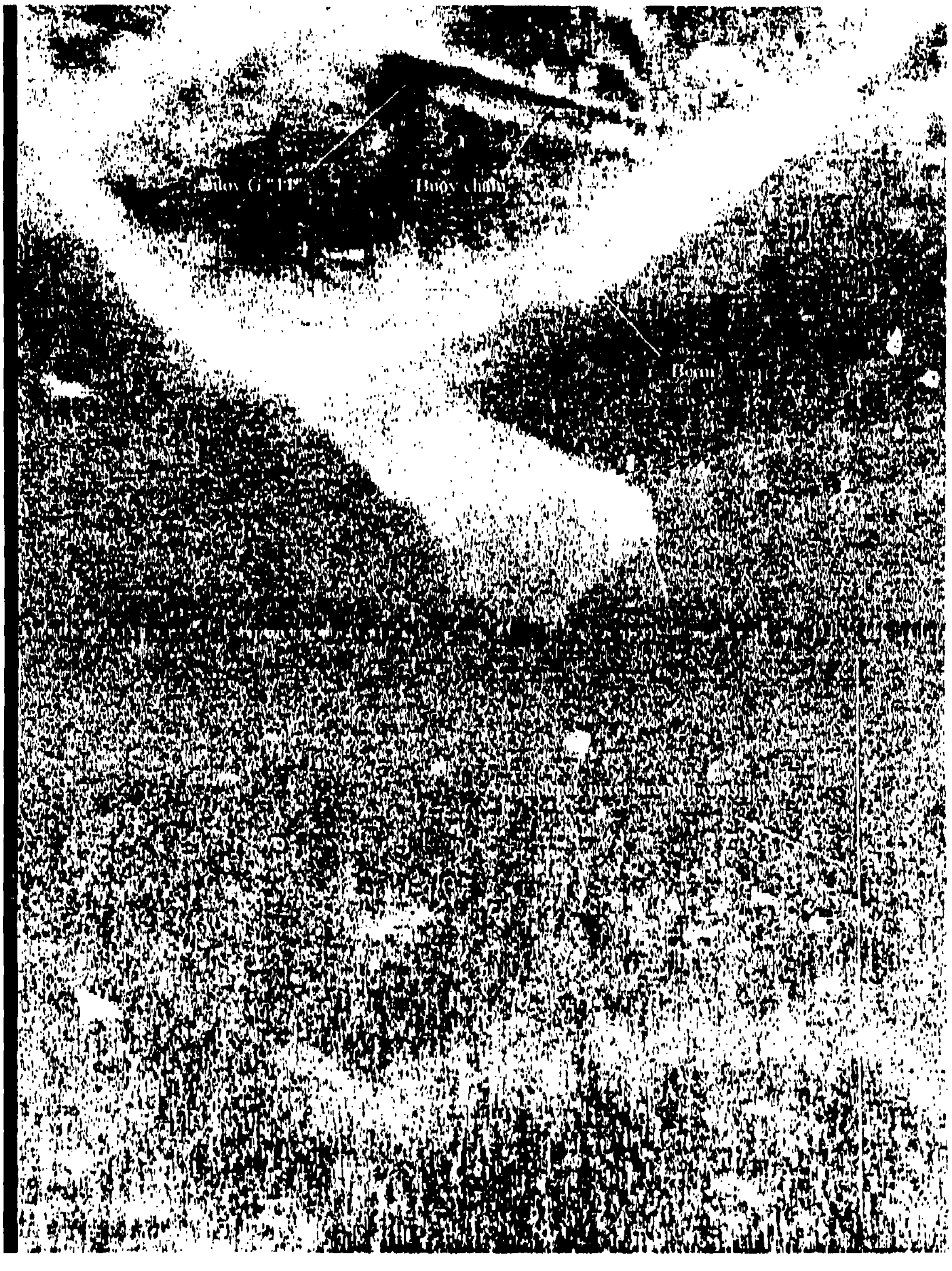


Figure 11. Berm and buoy G "11" image fully corrected for geometric and radiometric errors.

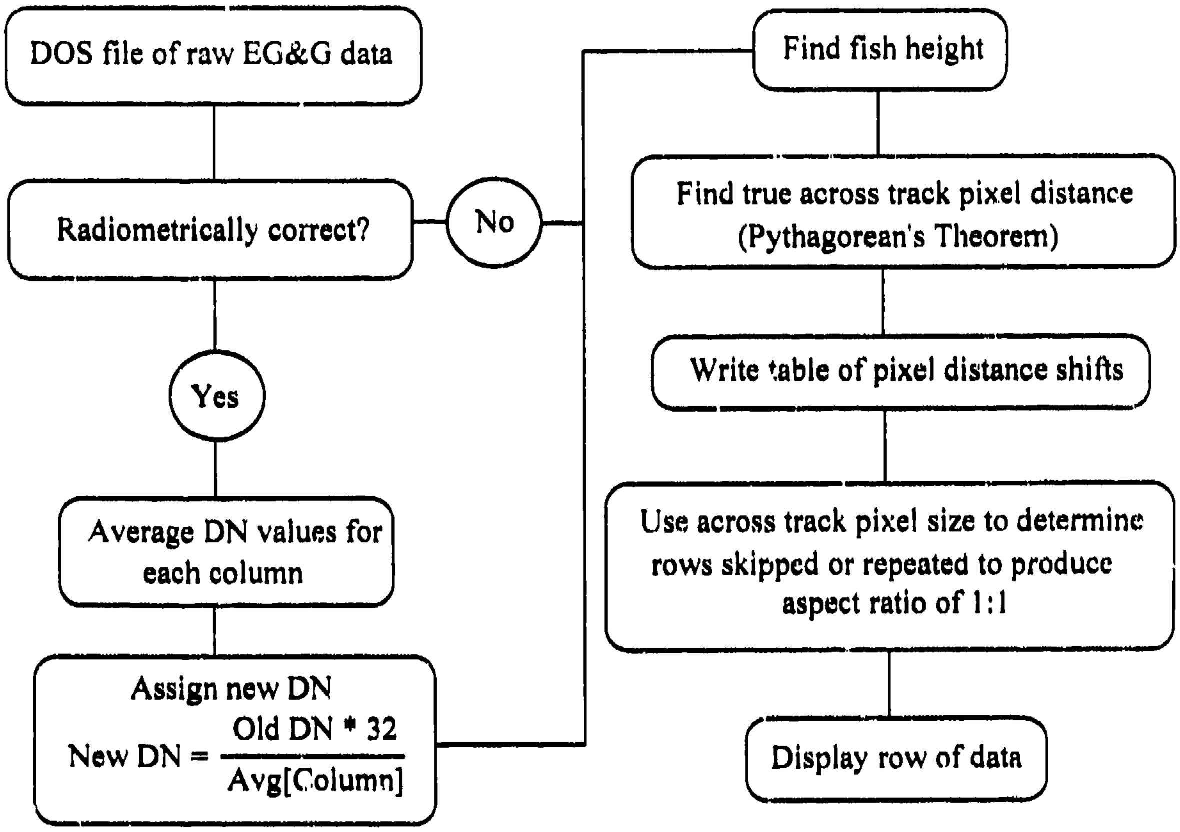

DOS file of raw EG&G data
Radiometrically correct?
No
Yes
Average DN values for each column
Assign new DN
New DN = Old DN * 32 / Avg[Column]
Find fish height
Find true across track pixel distance (Pythagorean's Theorem)
Write table of pixel distance shifts
Use across track pixel size to determine rows skipped or repeated to produce aspect ratio of 1:1
Display row of data

Figure 12. Geometric and radiometric corrections in SIDESCAN.

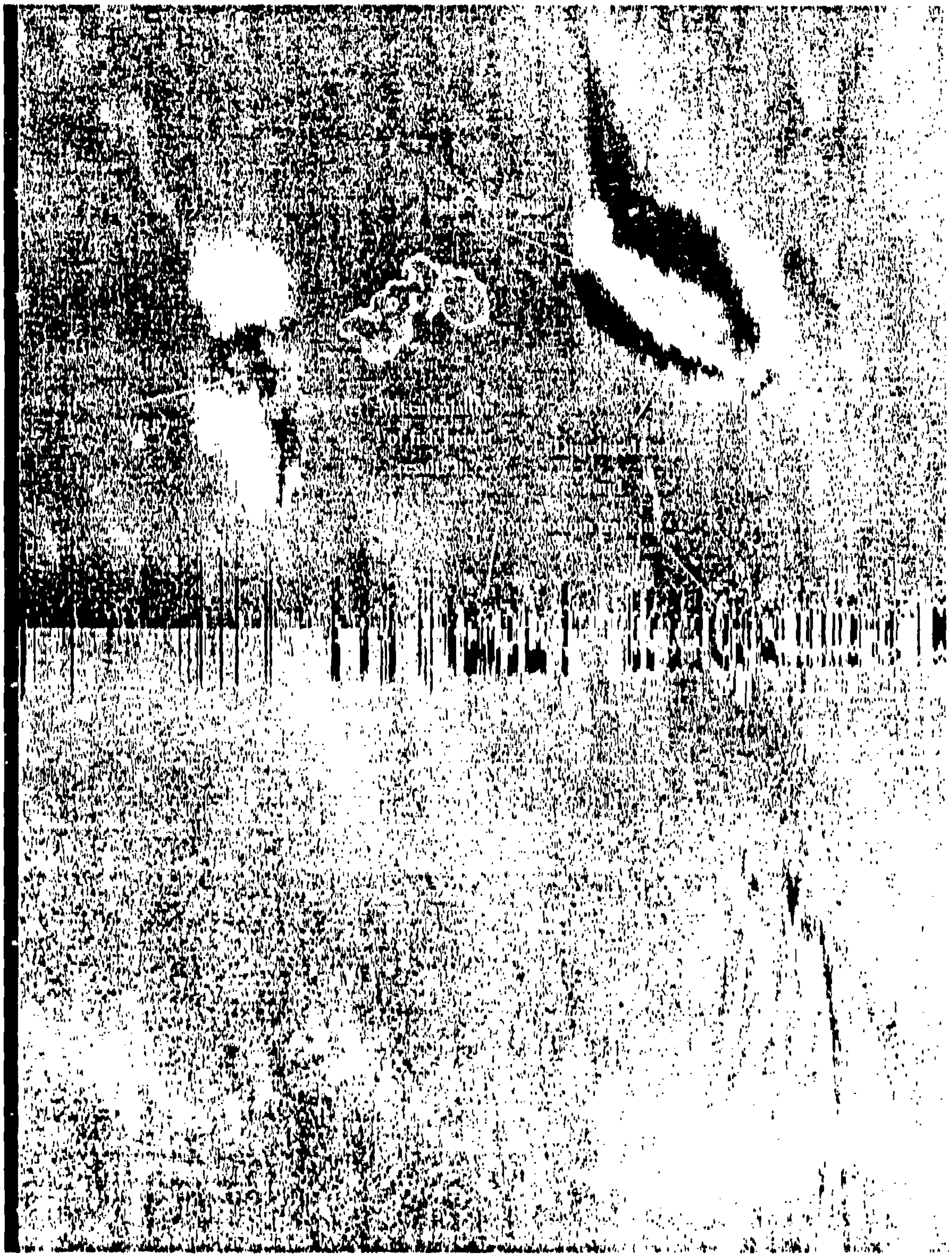


Figure 13. Image of barge and buoy "WR87" suffering from starboard transducer anomaly.

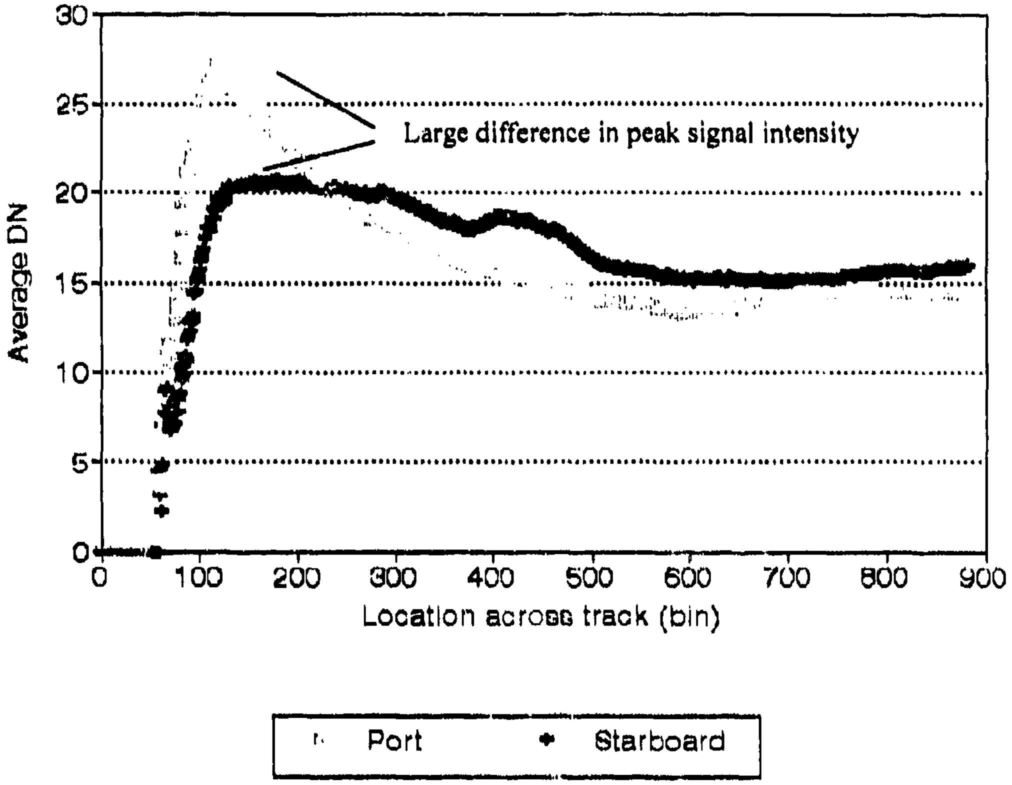


Figure 14. Average return strength vs. distance for distorted wreck and buoy "WR87" image.

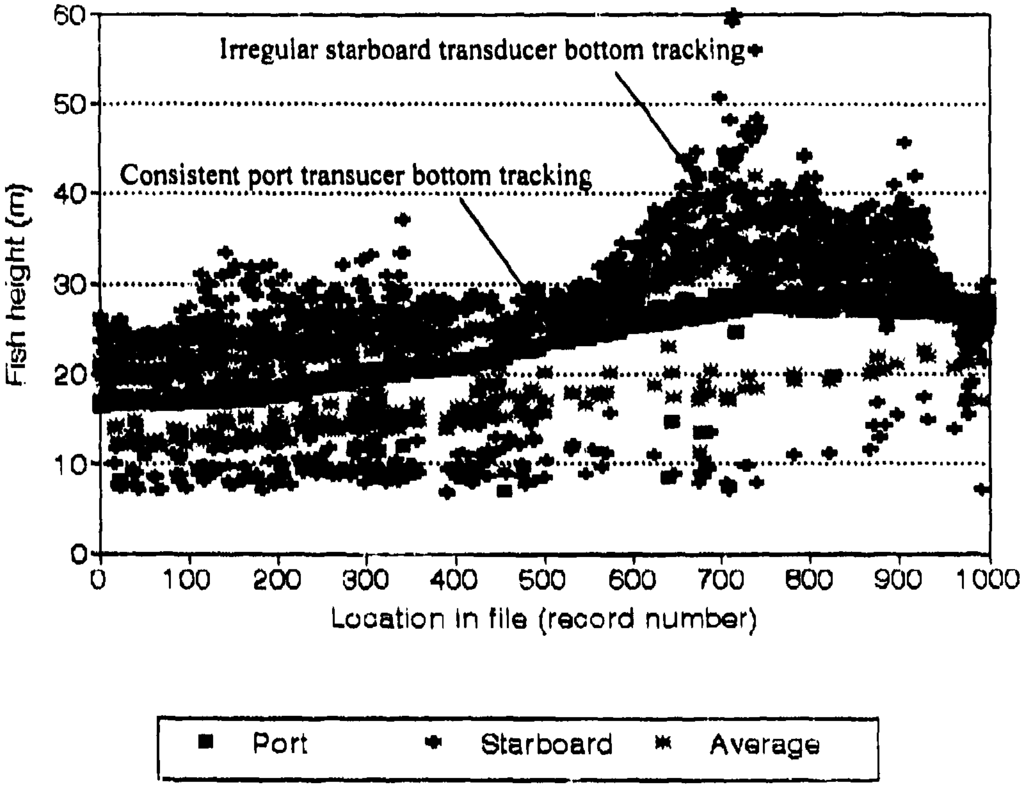


Figure 15. Calculated fish height based upon port, starboard, and average of both transducers.

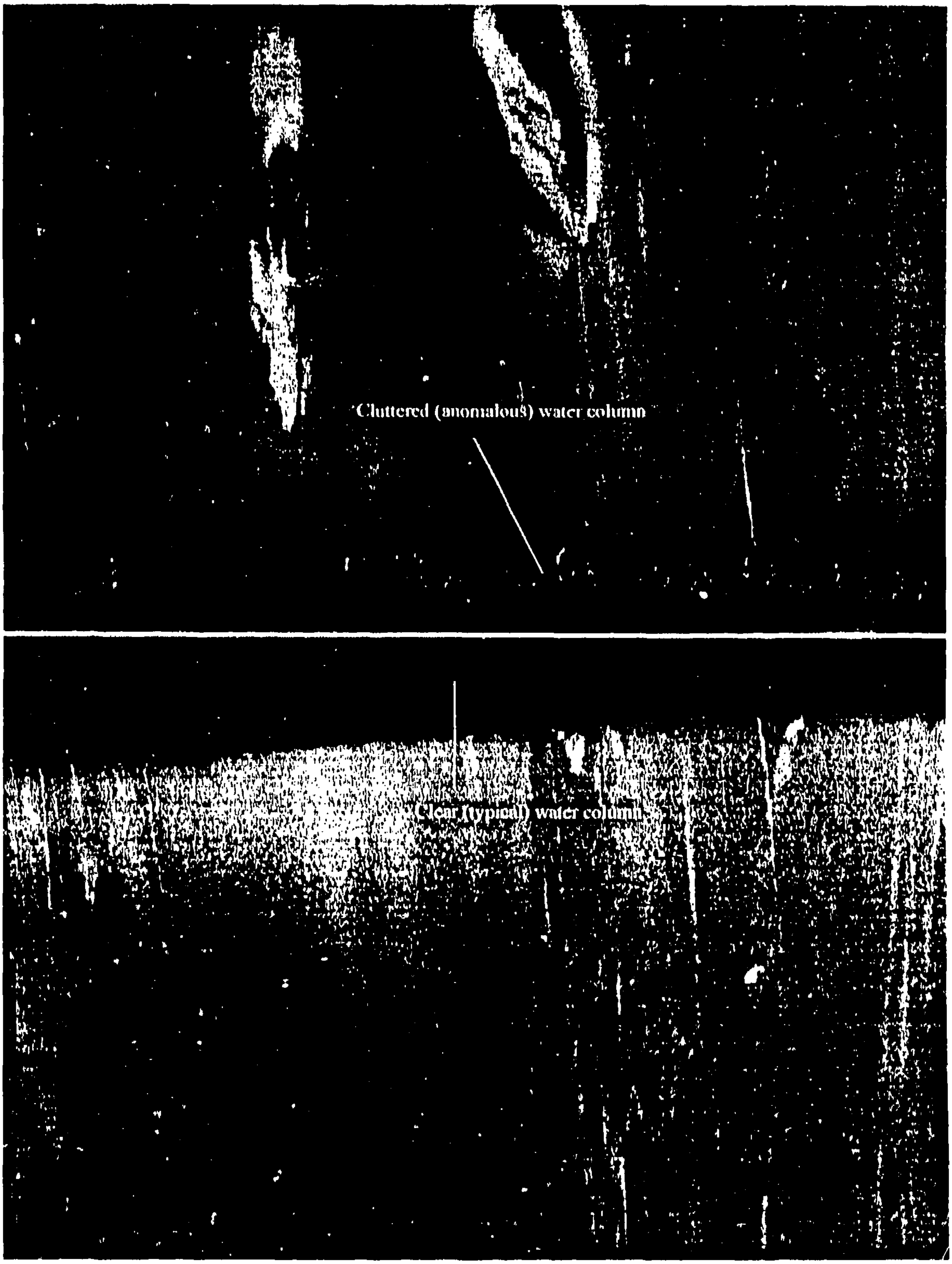

Cluttered (anomalous) water column
Clear (typical) water column

Figure 16. Raw image of wreck and buoy "WR87" showing clutter in starboard water column

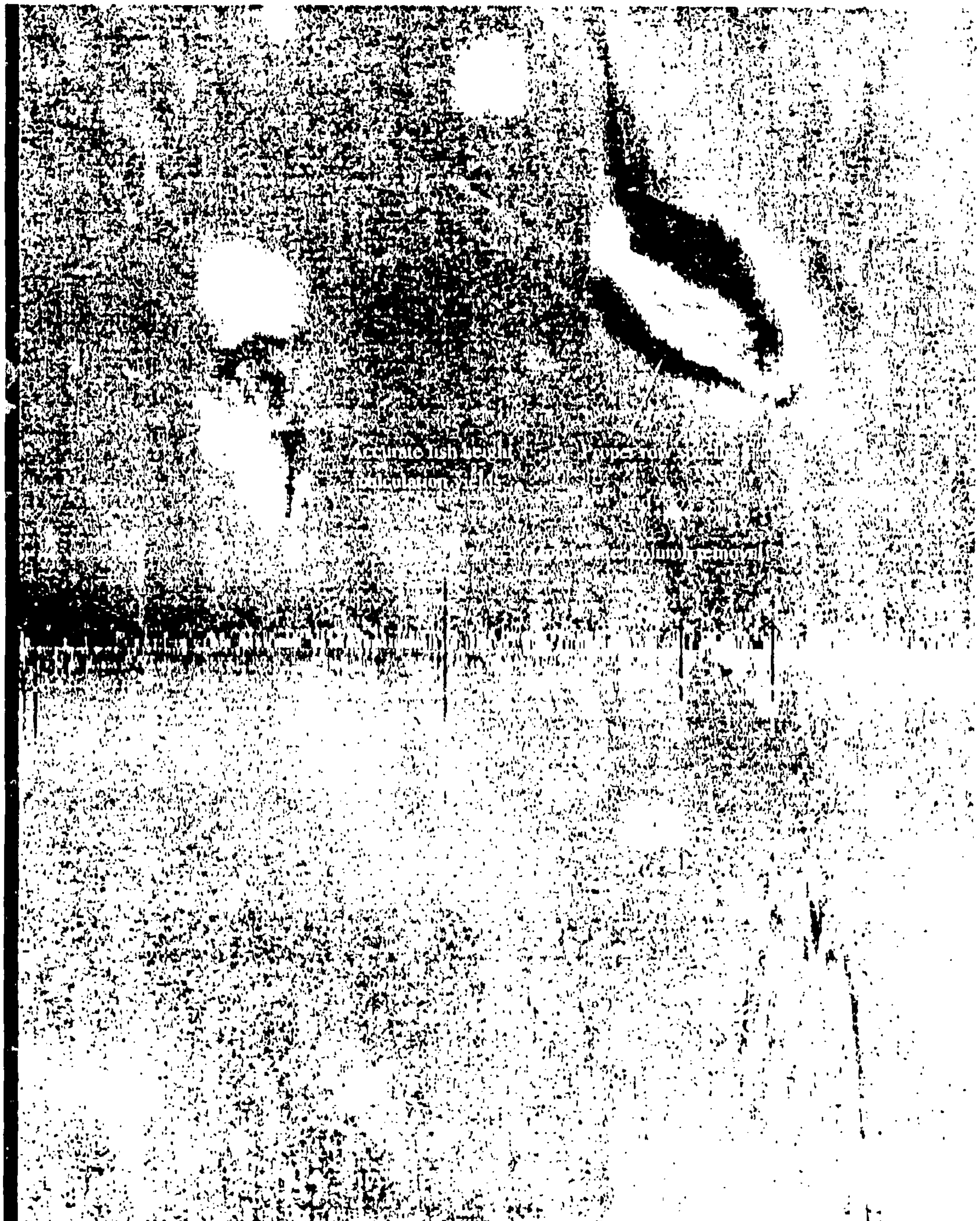


Figure 17. Sonograph of wreck and buoy "WR87" using the port transducer for bottom tracking

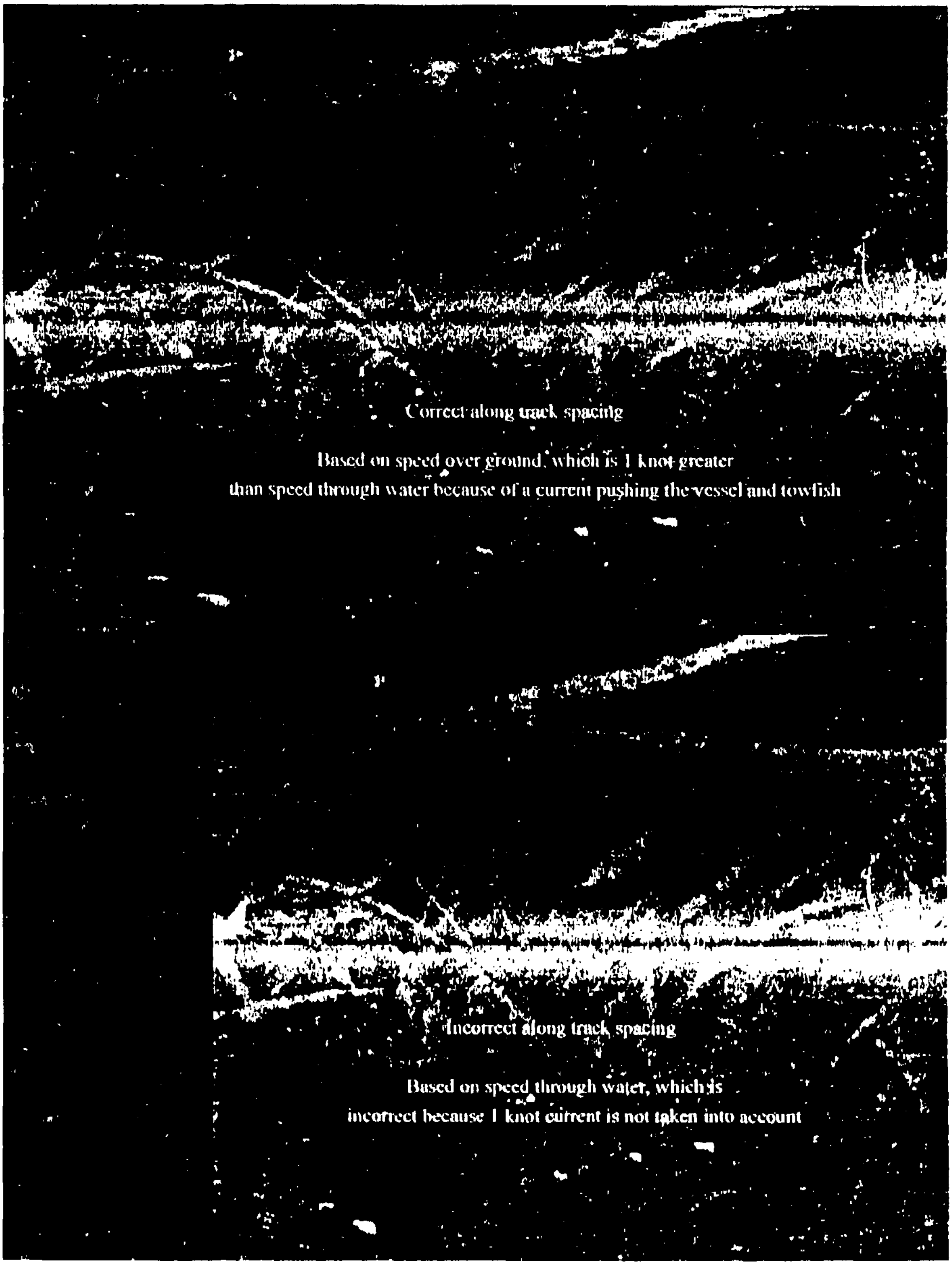

Correct along track spacing
Based on speed over ground, which is 1 knot greater
than speed through water because of a current pushing the vessel and towfish
Incorrect along track spacing
Based on speed through water, which is
incorrect because 1 knot current is not taken into account

Figure 18. Comparison of along track spacing for two identical files based on speed through water and speed over ground

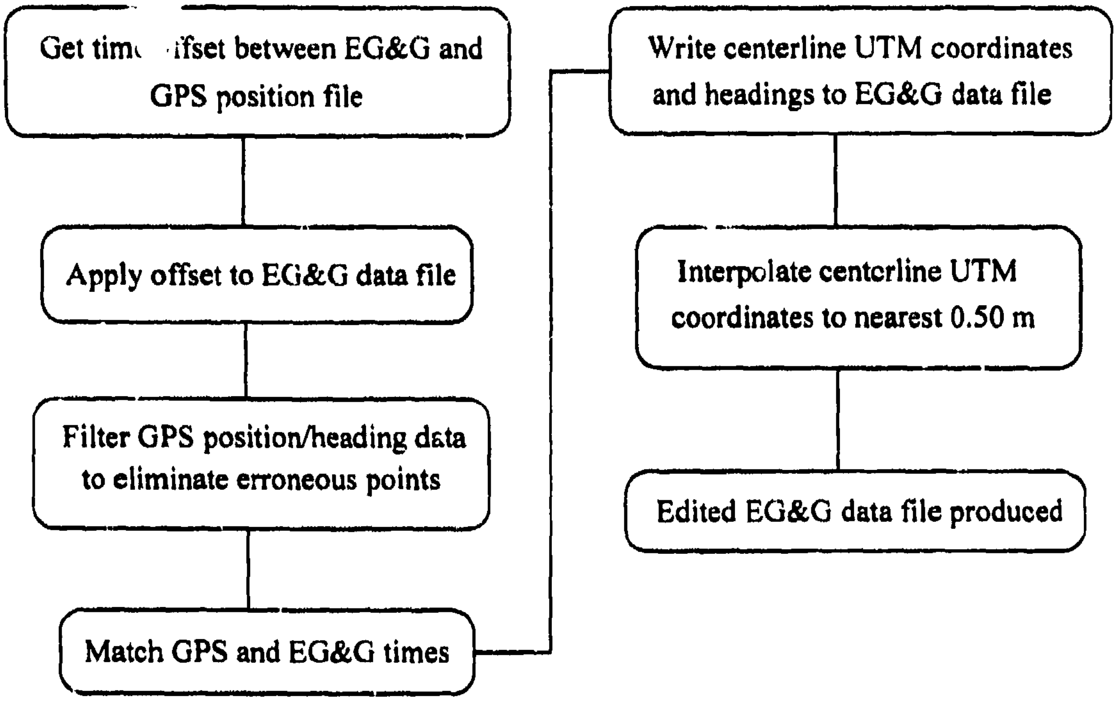

Get timı ·ffset between EG&G and GPS position file
Apply offset to EG&G data file
Filter GPS position/heading data to eliminate erroneous points
Match GPS and EG&G times
Write centerline UTM coordinates and headings to EG&G data file
Interpolate centerline UTM coordinates to nearest 0.50 m
Edited EG&G data file produced

Figure 19. Ground registration in SIDESCAN.

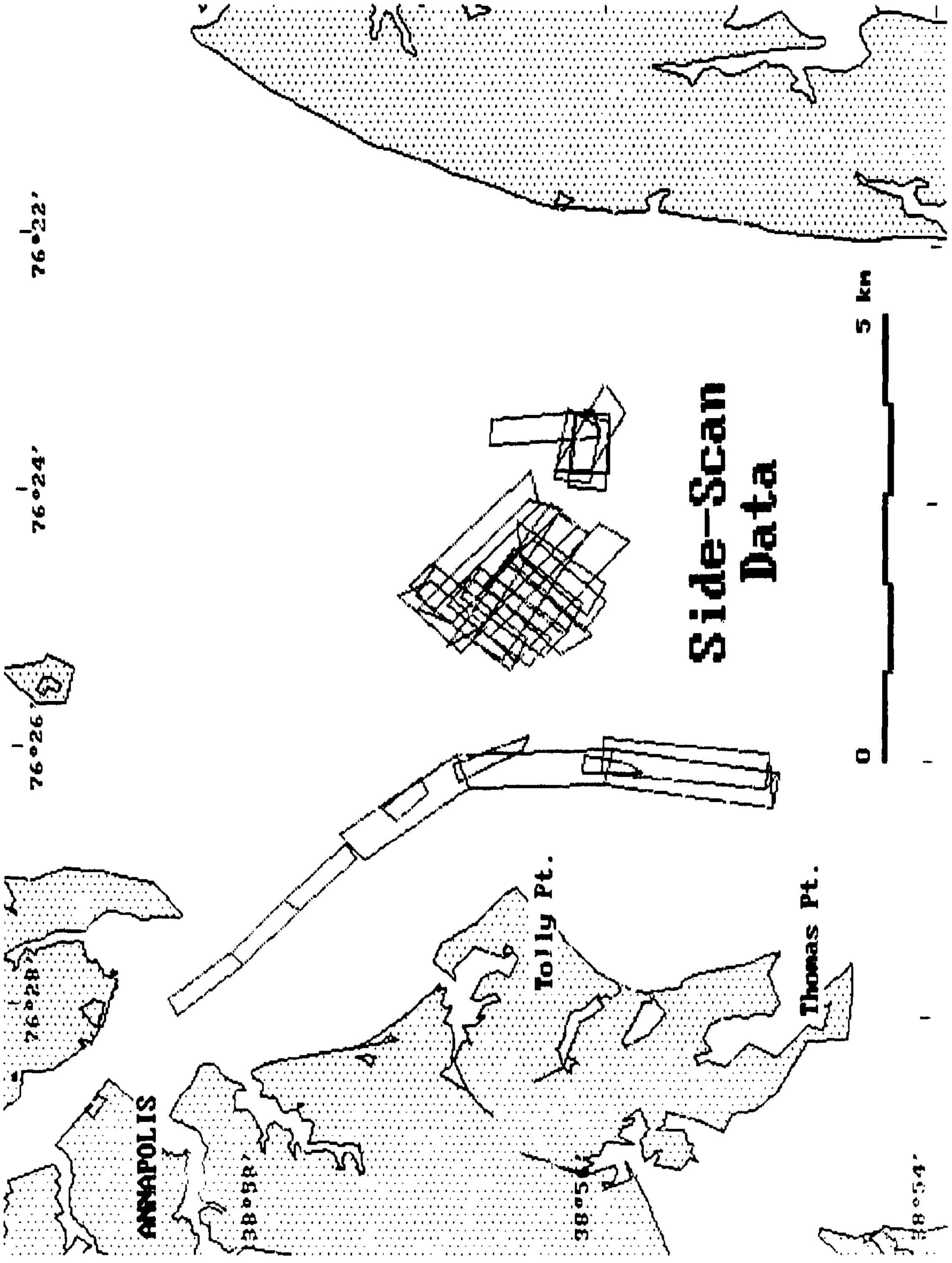


Figure 20. Fully corrected and ground registered side-scan image files.

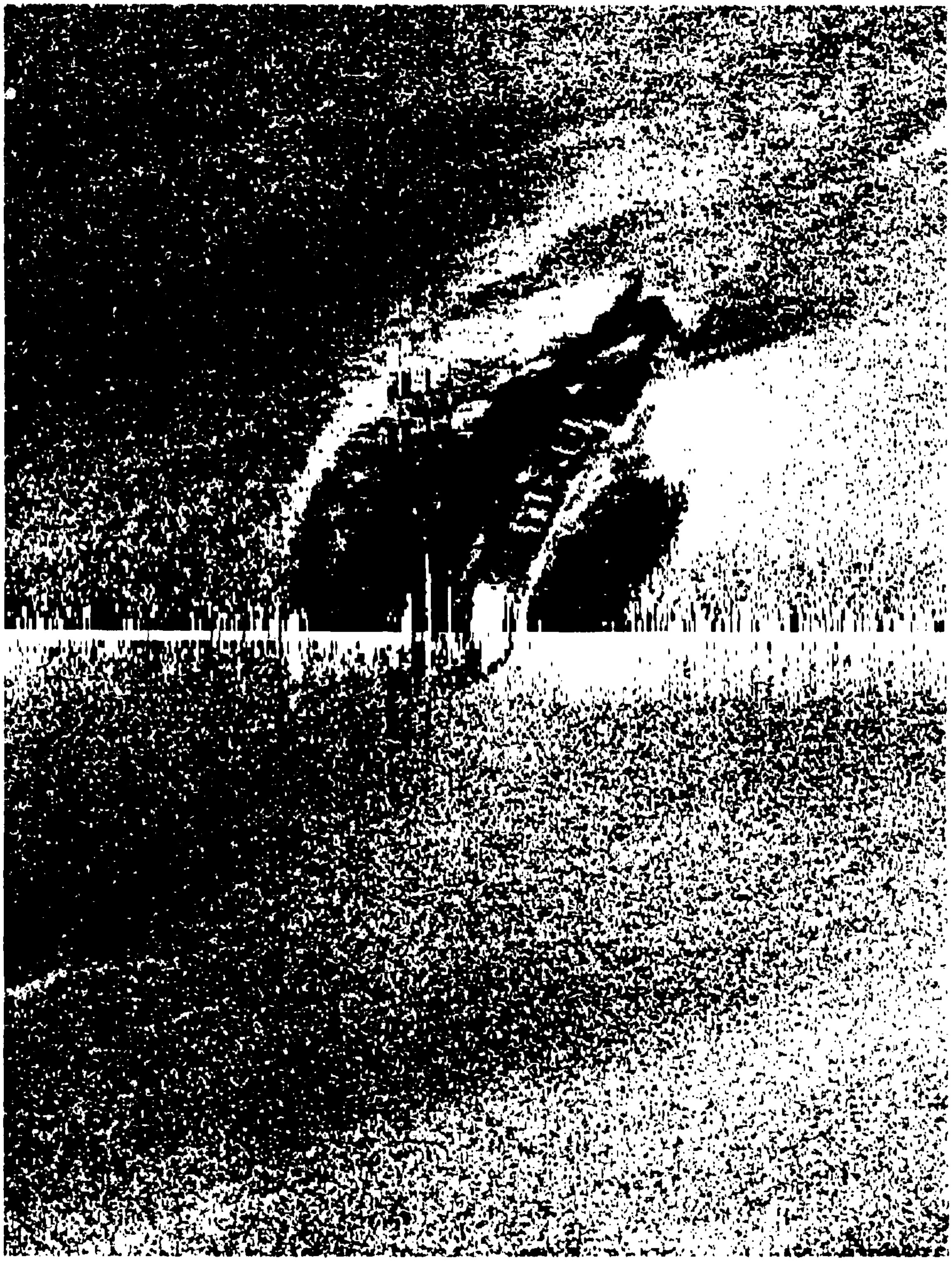


Figure 21. Unfiltered sonograph of barge wreckage.

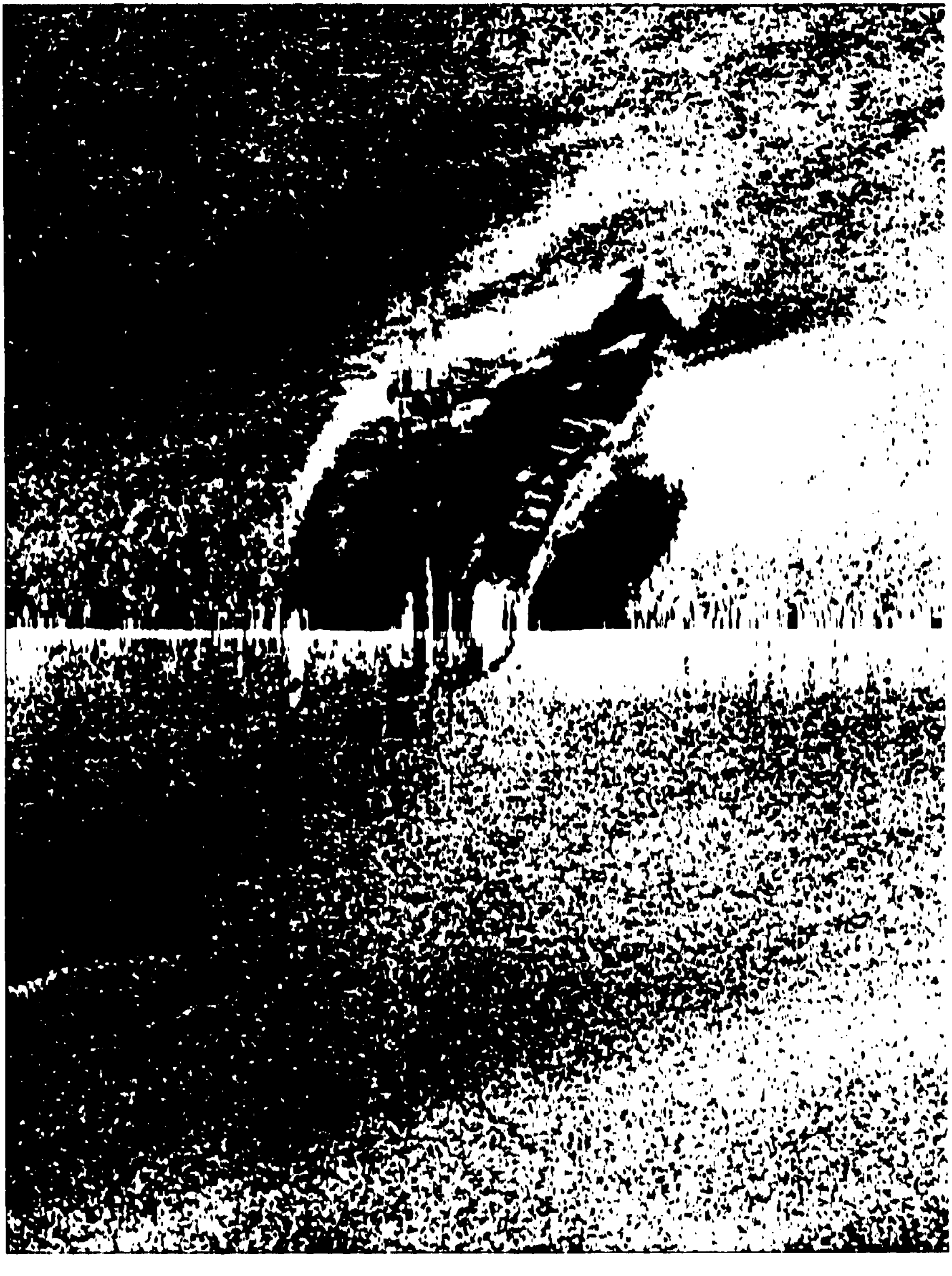


Figure 22. 3 x 3 smoothing filter applied to image of barge wreckage. Much of the speckle noise has been removed without sacrificing detail.

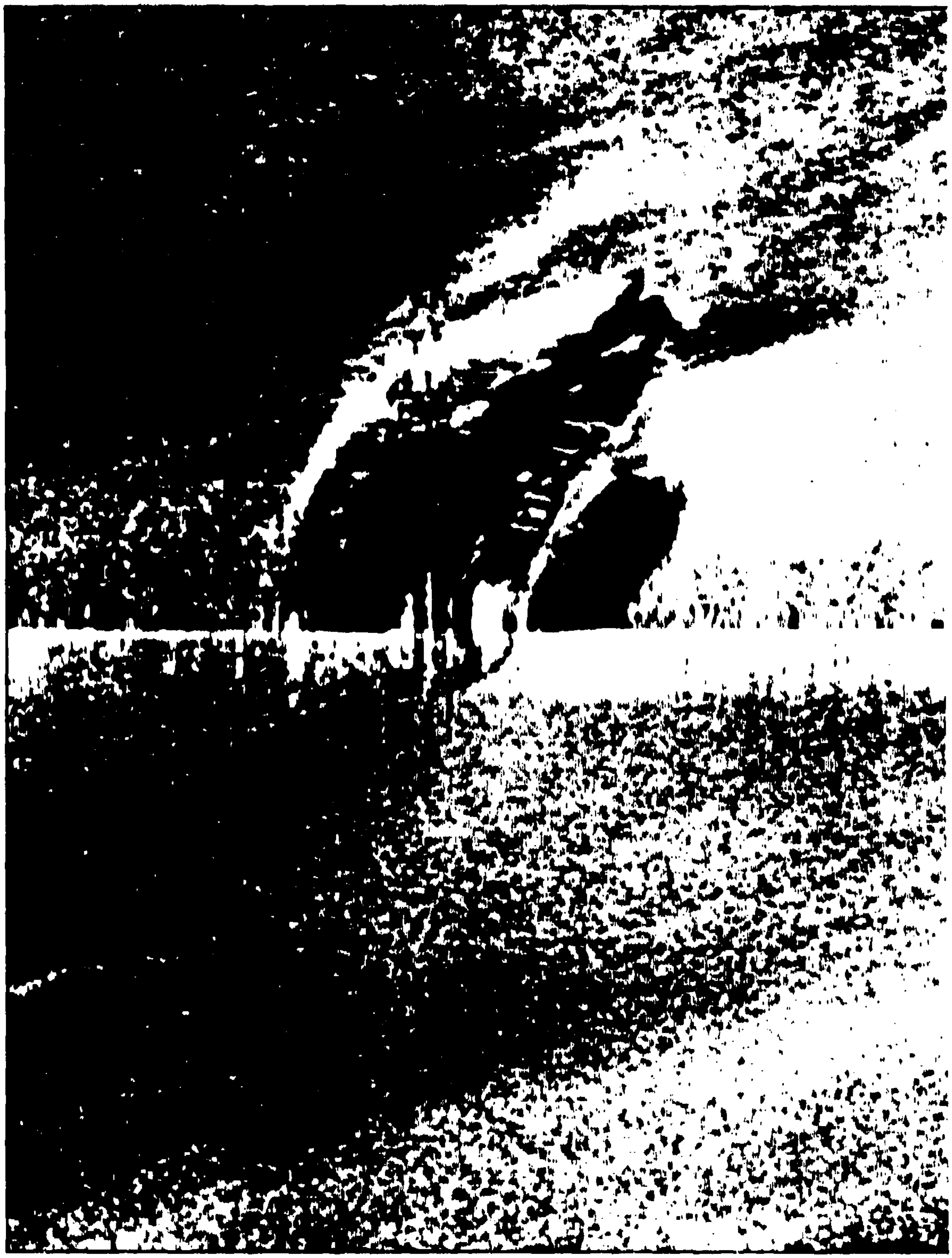


Figure 23. 5 x 5 smoothing filter applied to image of barge wreckage. Although speckle noise is further lessened, excessive averaging of pixel DNs has destroyed details.

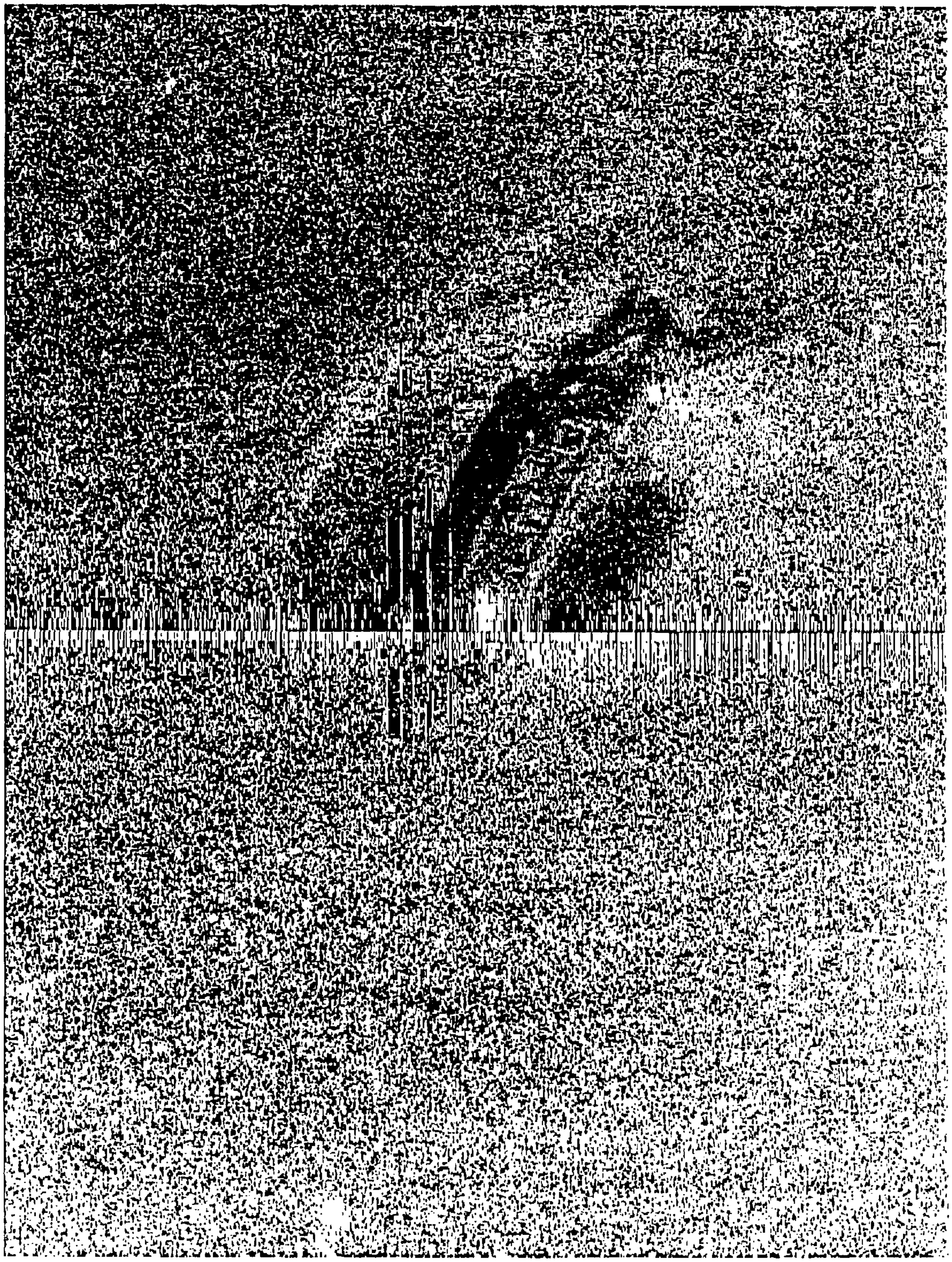


Figure 24. Edge filter applied to image of barge wreckage. The barge is emphasized and the rest of the image is deemphasized

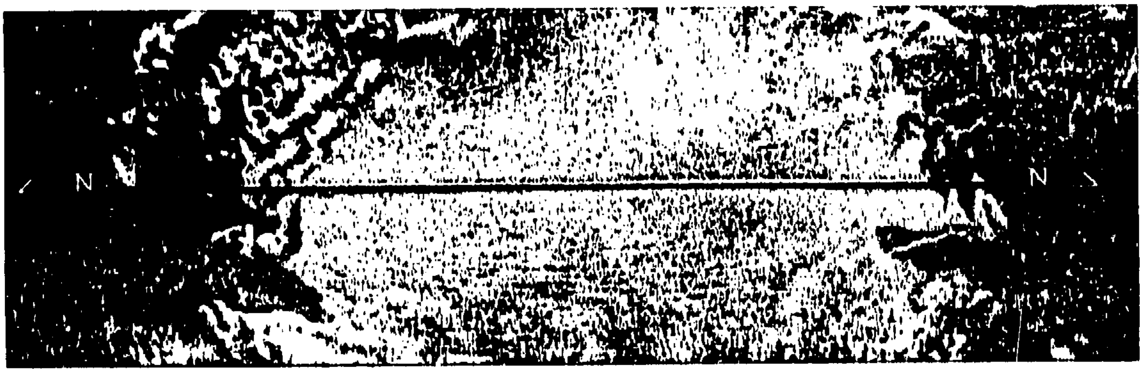


Figure 25. Sonograph of a 180 degree turn over the Thomas Point oyster bar shows the limitations of a traditional display, where turns, course deviations, and data overlap are not apparent.

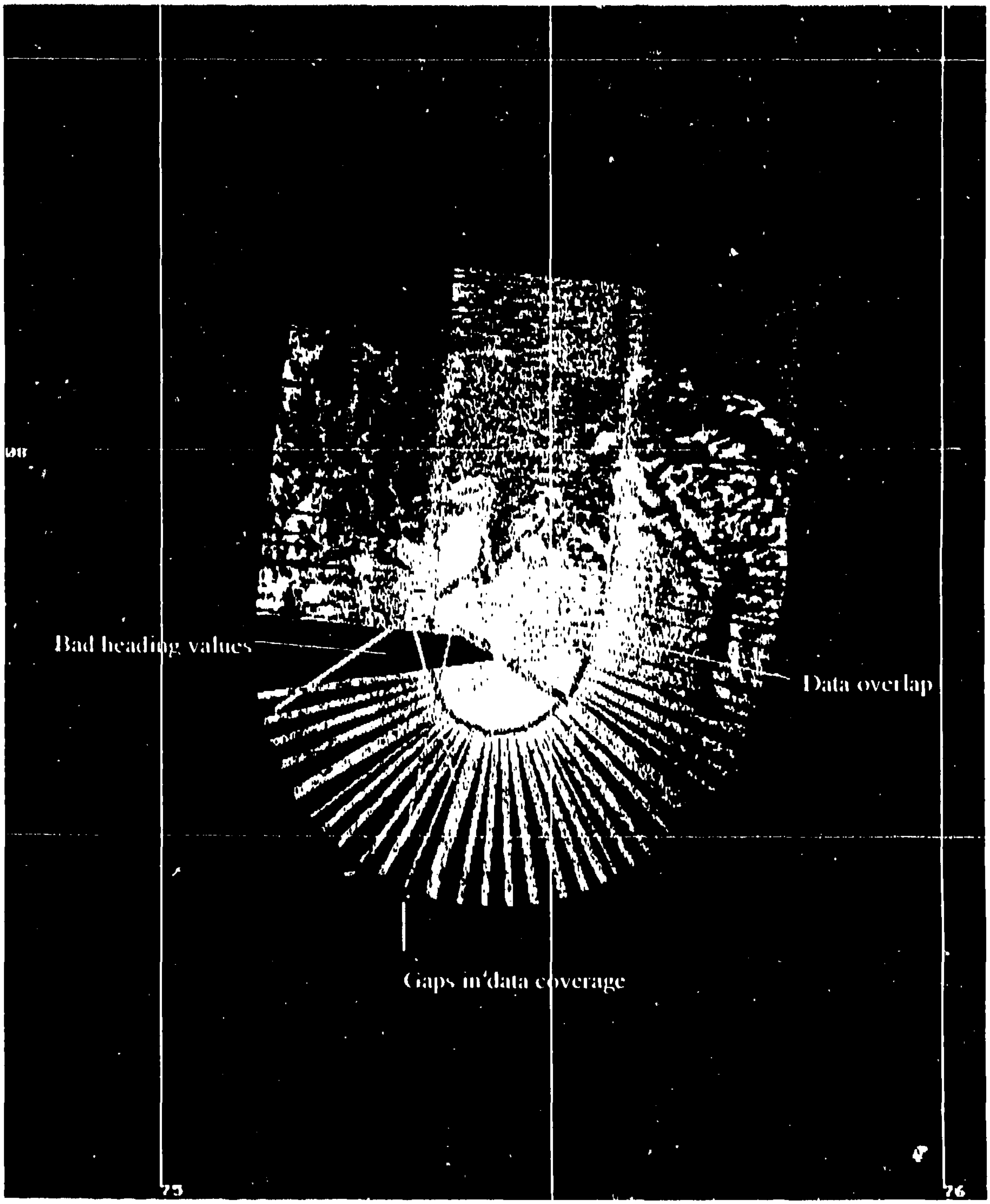


Figure 26. The same sonograph as Figure 25, except data was written to a projection based on UTM centerline values and headings

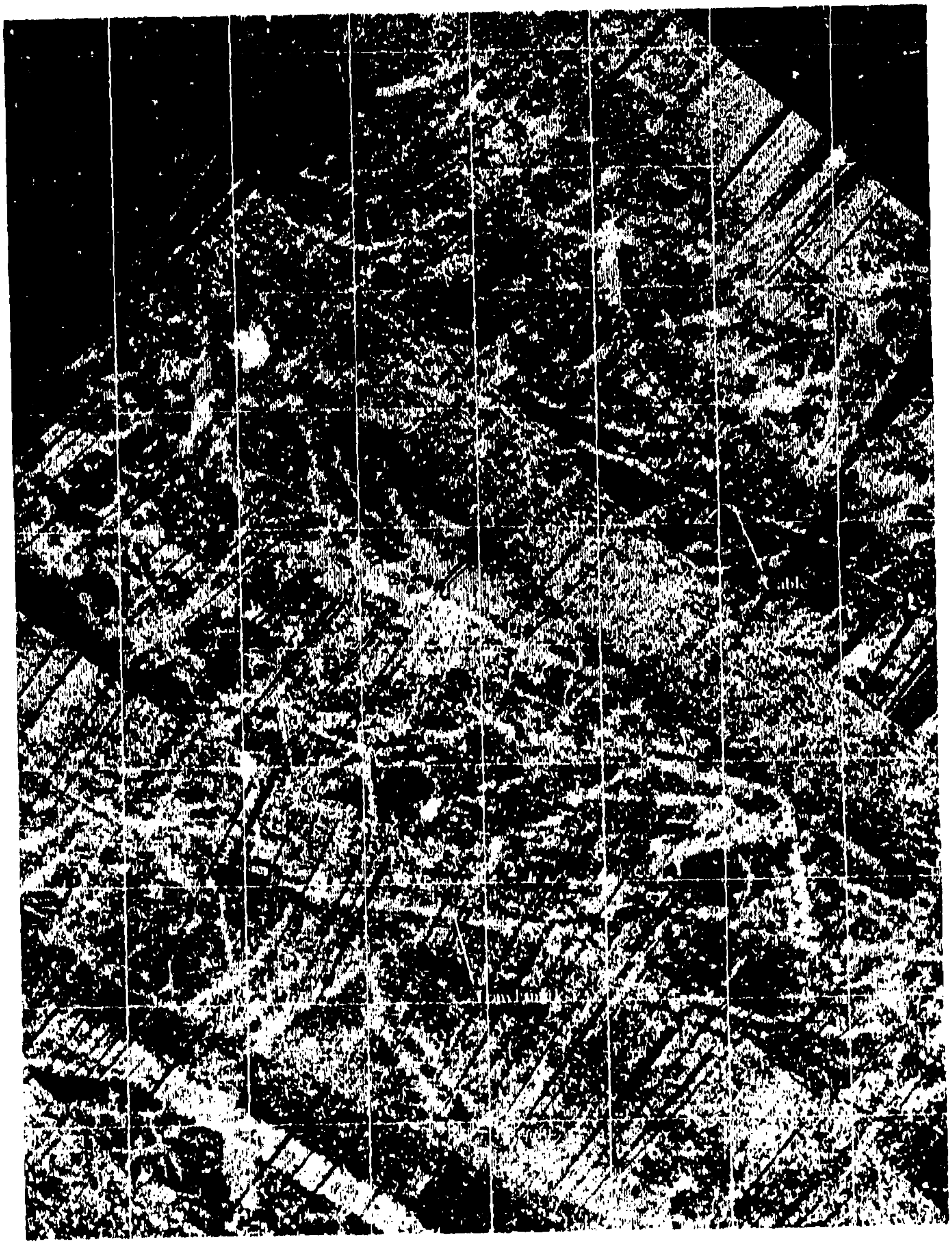


Figure 27. Southwest look angle mosaic of the mid Chesapeake Bay

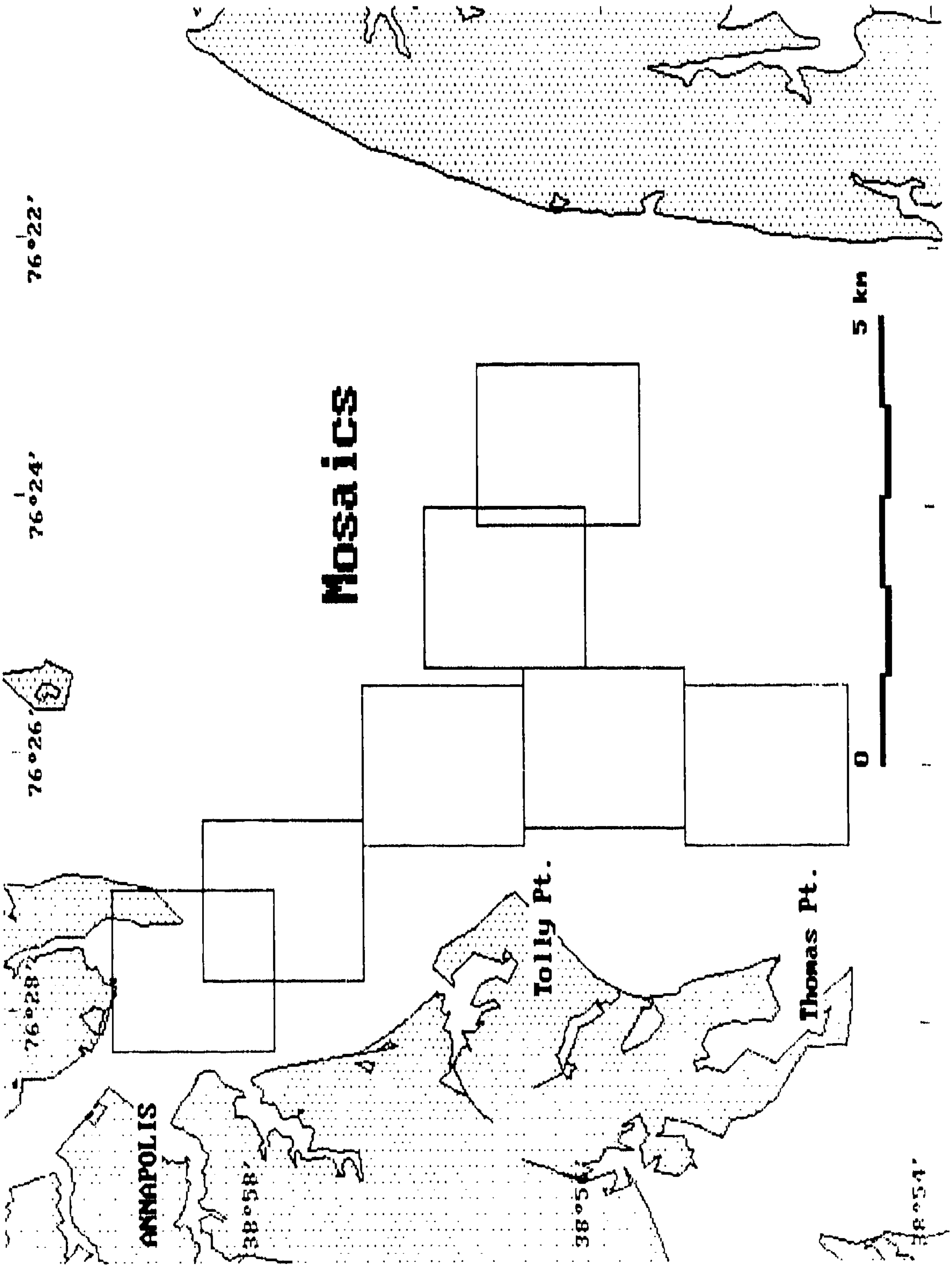


Figure 28. Outlines of mosaics created using SIDESCAN.

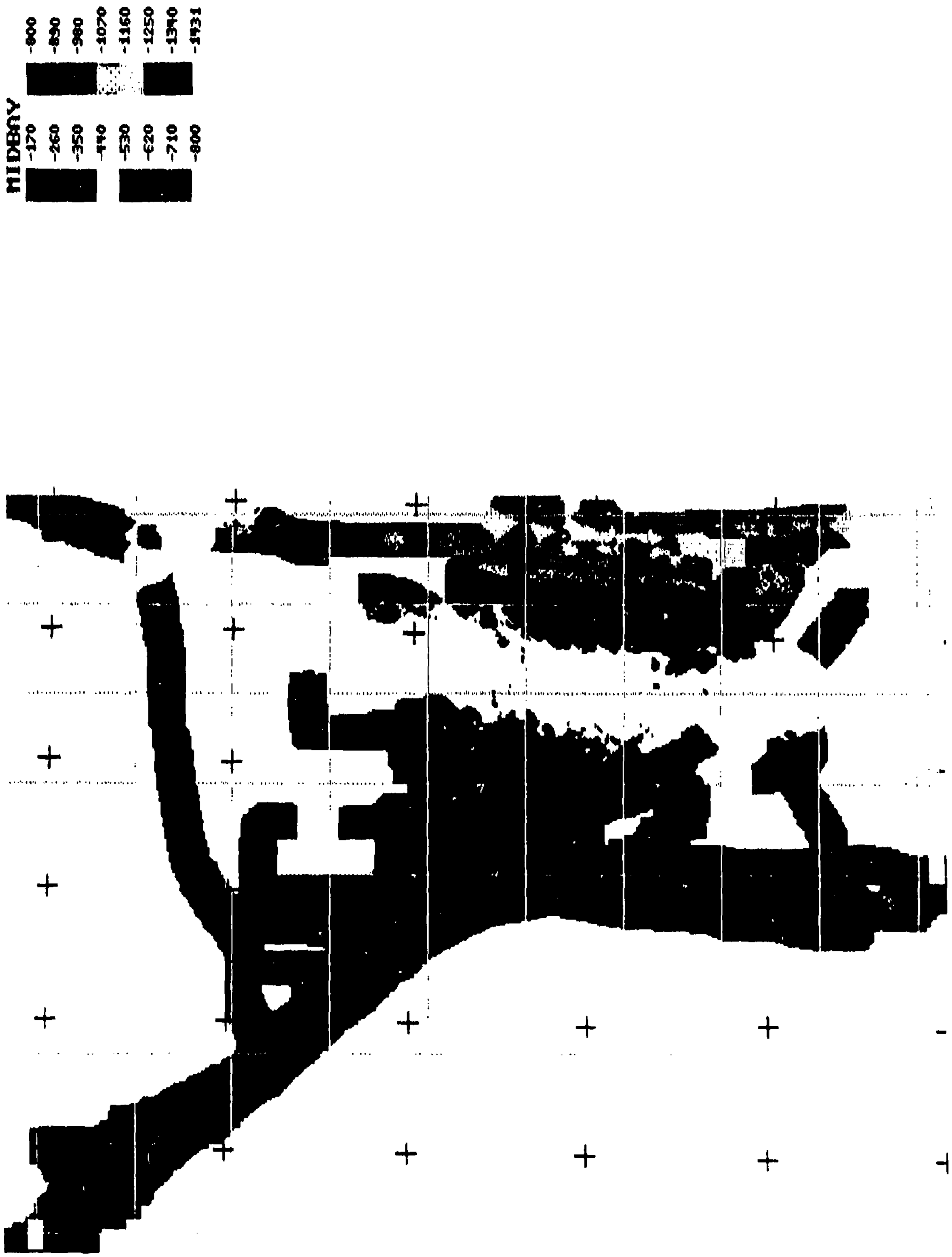


Figure 29. Digital elevation model (DEM) of study area.

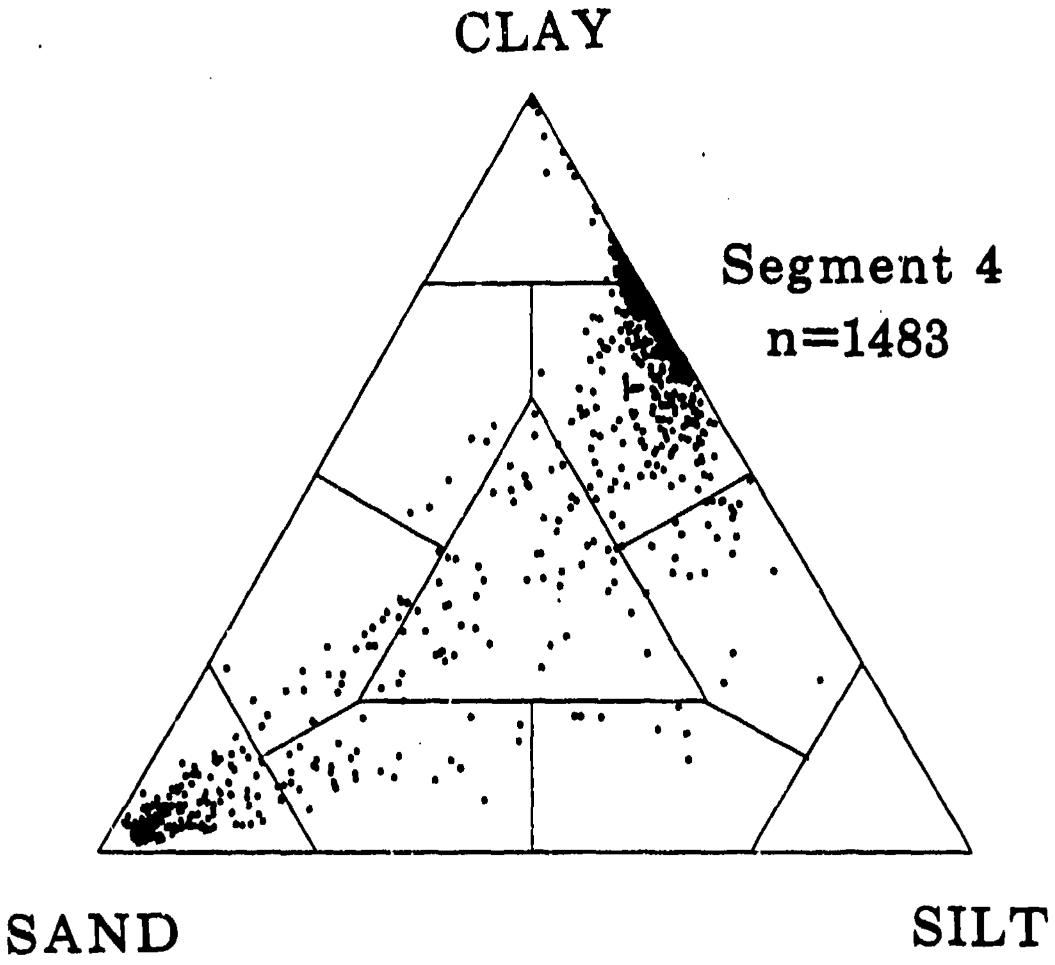


Figure 30. Tertiary diagram of sediment samples collected by *Kerhin et al.* [1988] in the Maryland portion of the Chesapeake Bay from the Severn River to the Patuxent River.

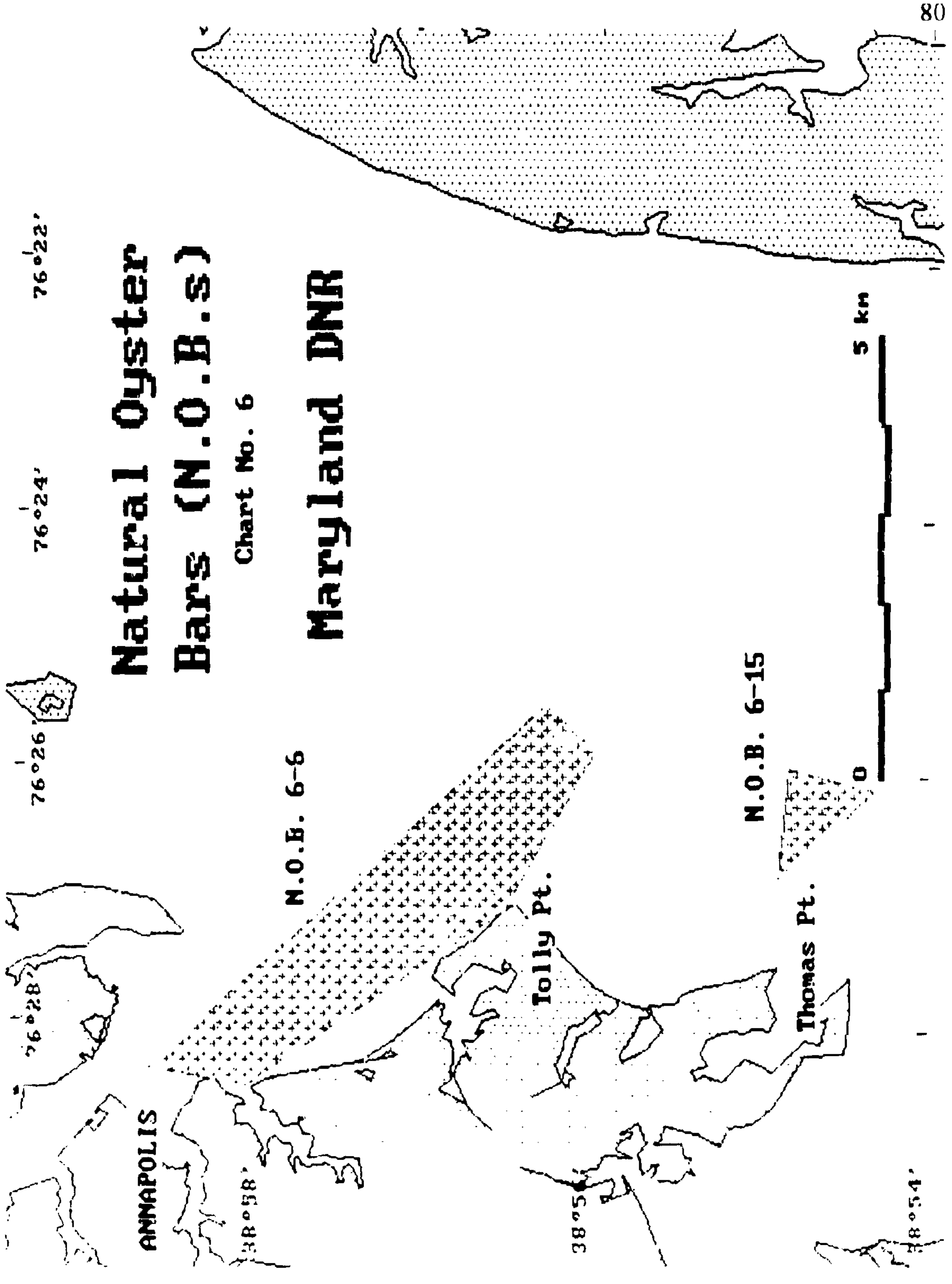


Figure 31. Outlines of Natural Oyster Bars 6-6 (Tolly Point) and 6-15 (Thomas Point) [*Department of Natural Resources, State of Maryland*, 1961]

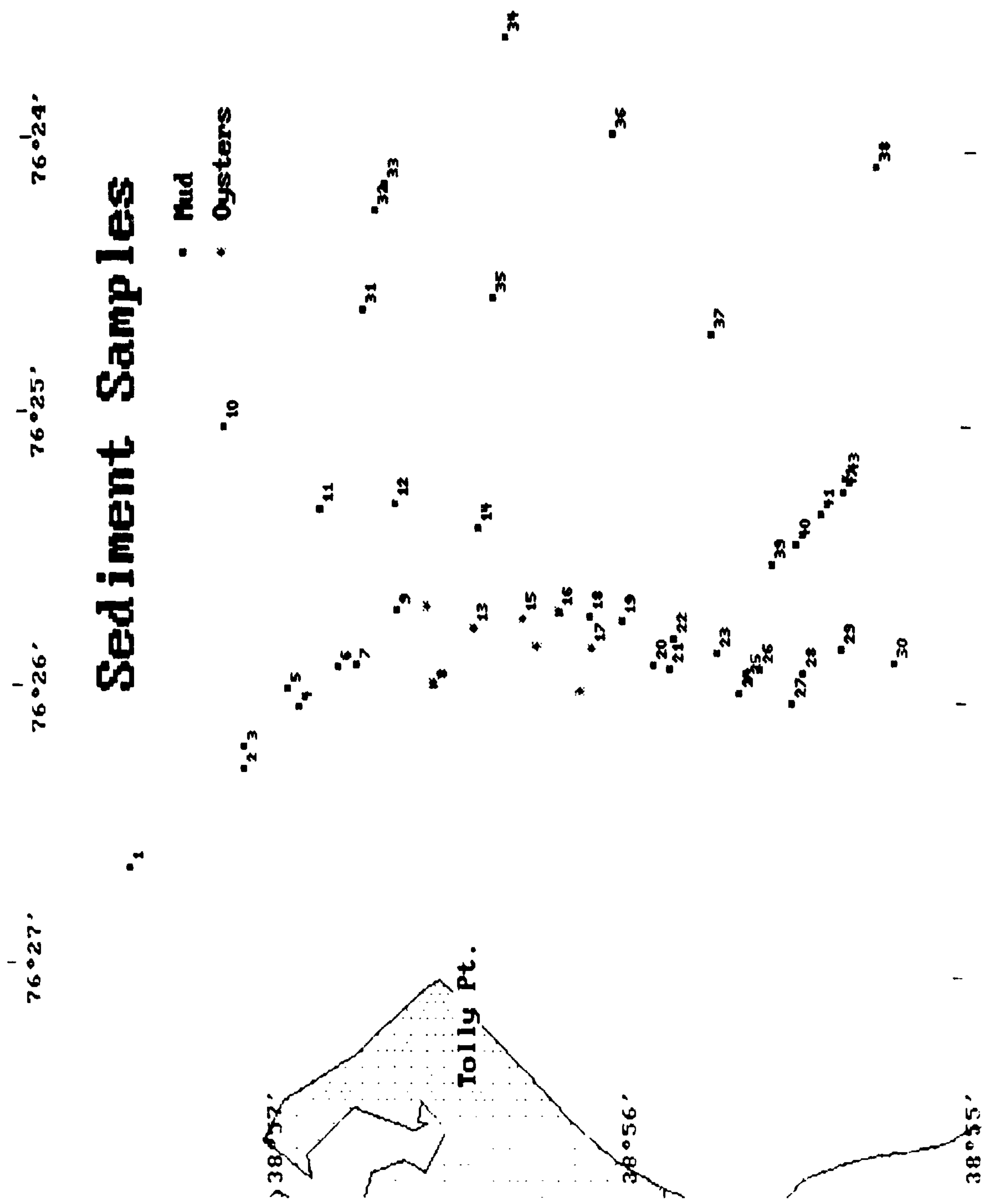


Figure 32. Locations of sediment samples collected with orange peel grab.

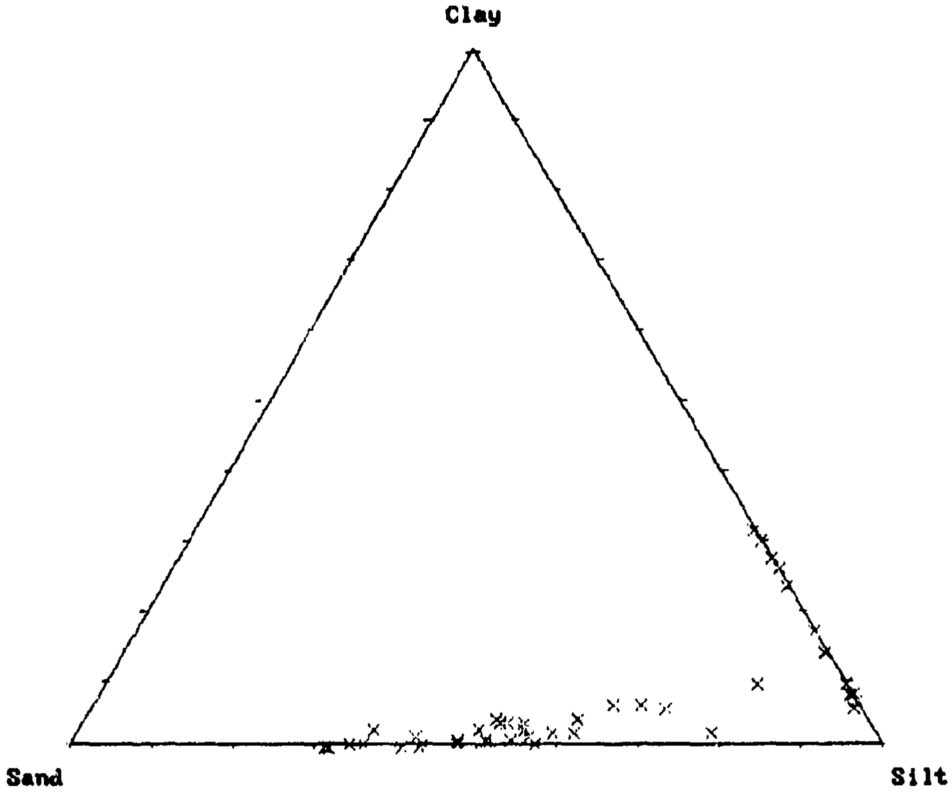


Figure 33. Tertiary diagram of sediment samples collected in the study area.

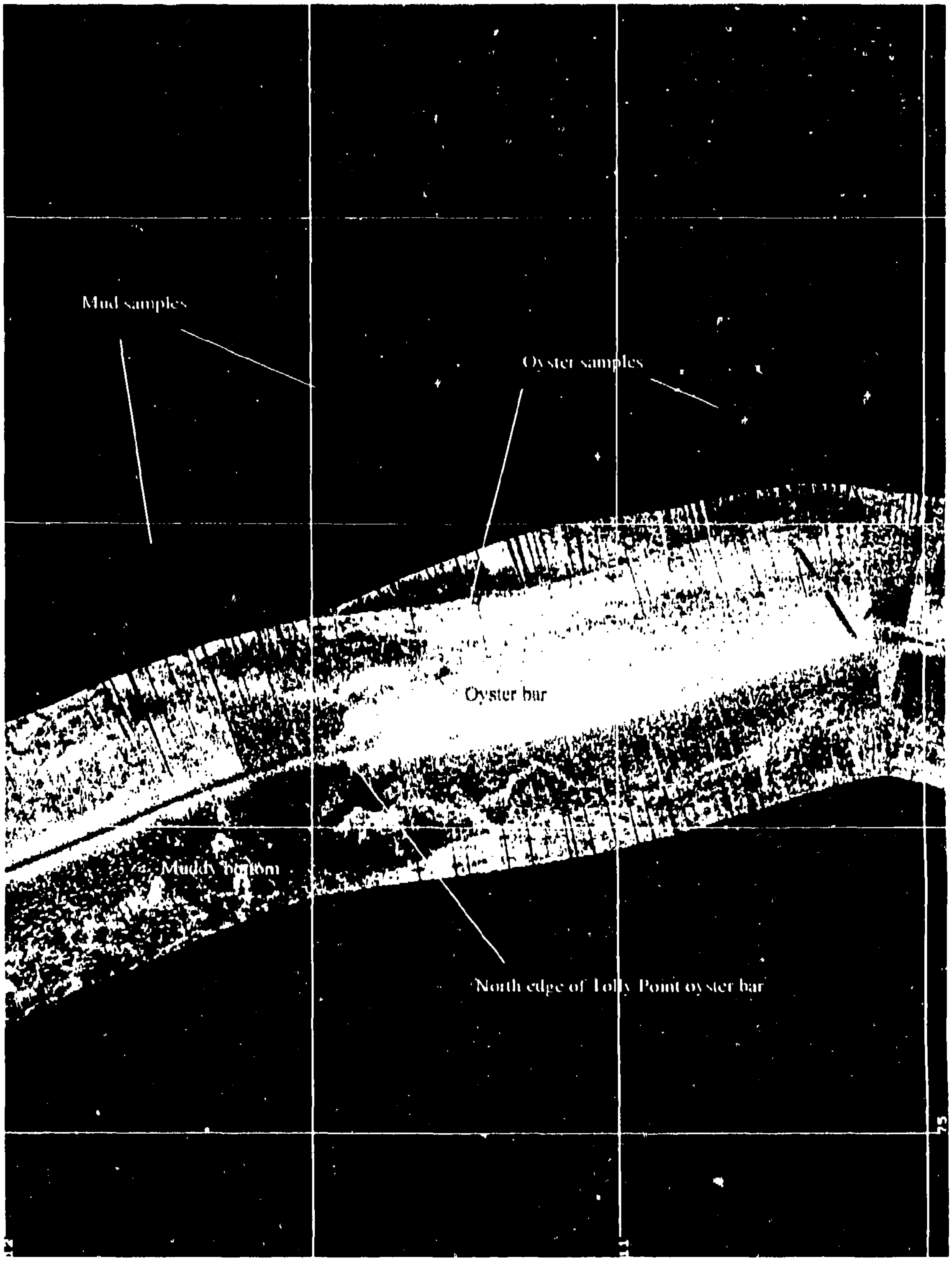


Figure 34. Mud and oyster sediment samples plotted on Folly Point oyster bar mosaic

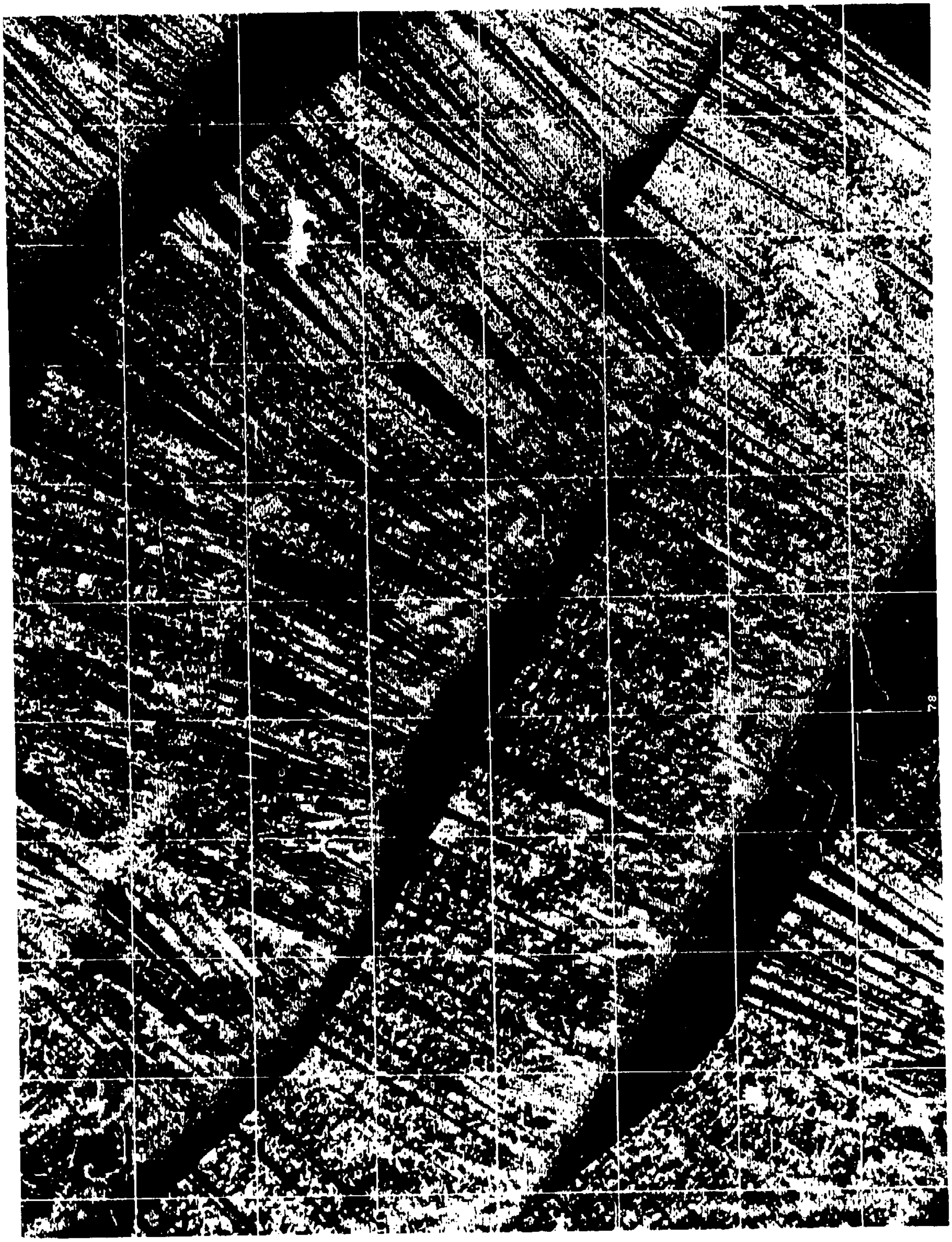


Figure 35. Northeast look angle mosaic of the mid Chesapeake Bay overlaid with 2 foot contours. The flatness of this region implies that the bathymetry does not significantly affect backscatter values.

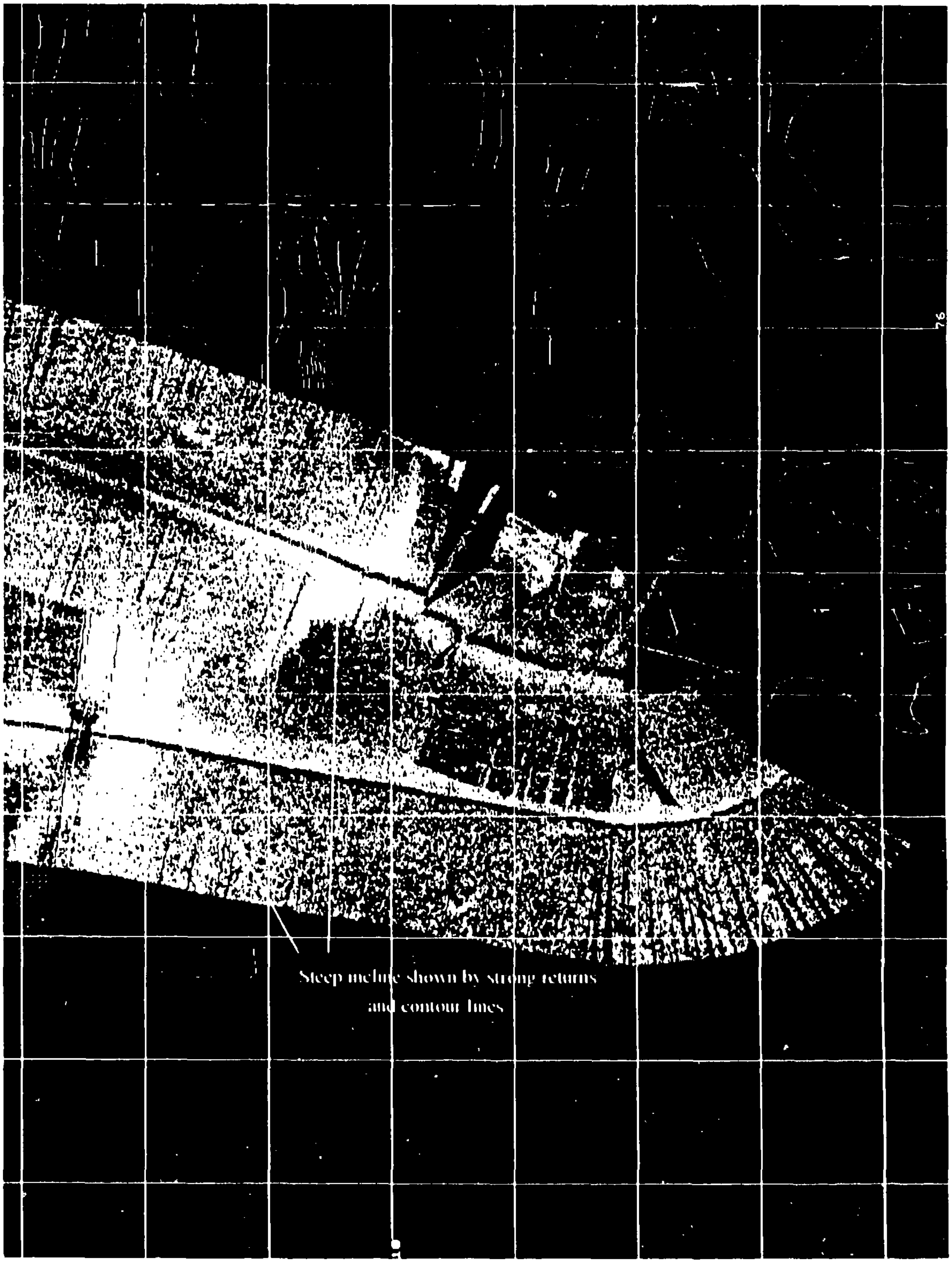


Figure 36. Southern edge of the Tolly Point oyster bar

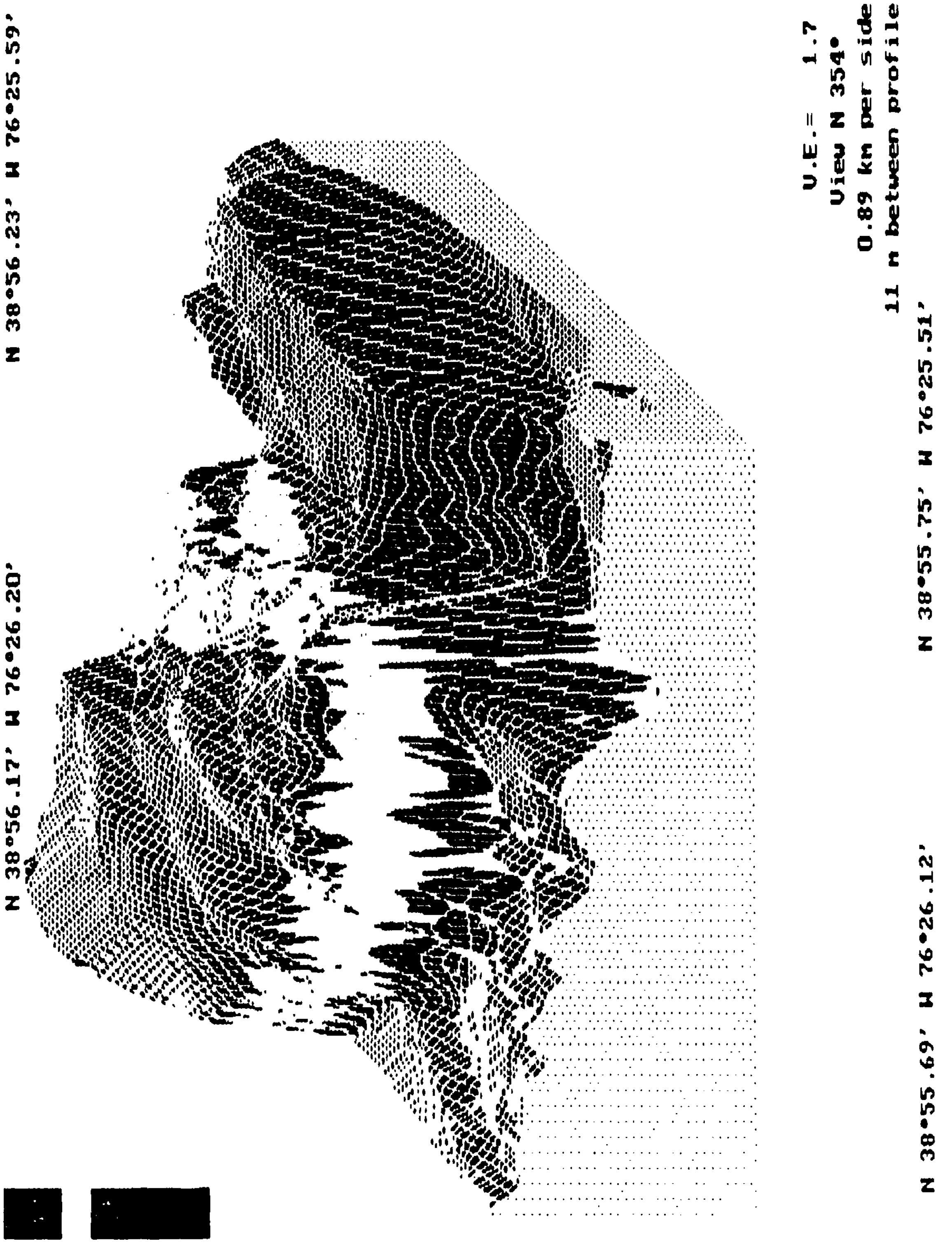


Figure 37. Oblique view of the southern edge of Tolly Point oyster bar

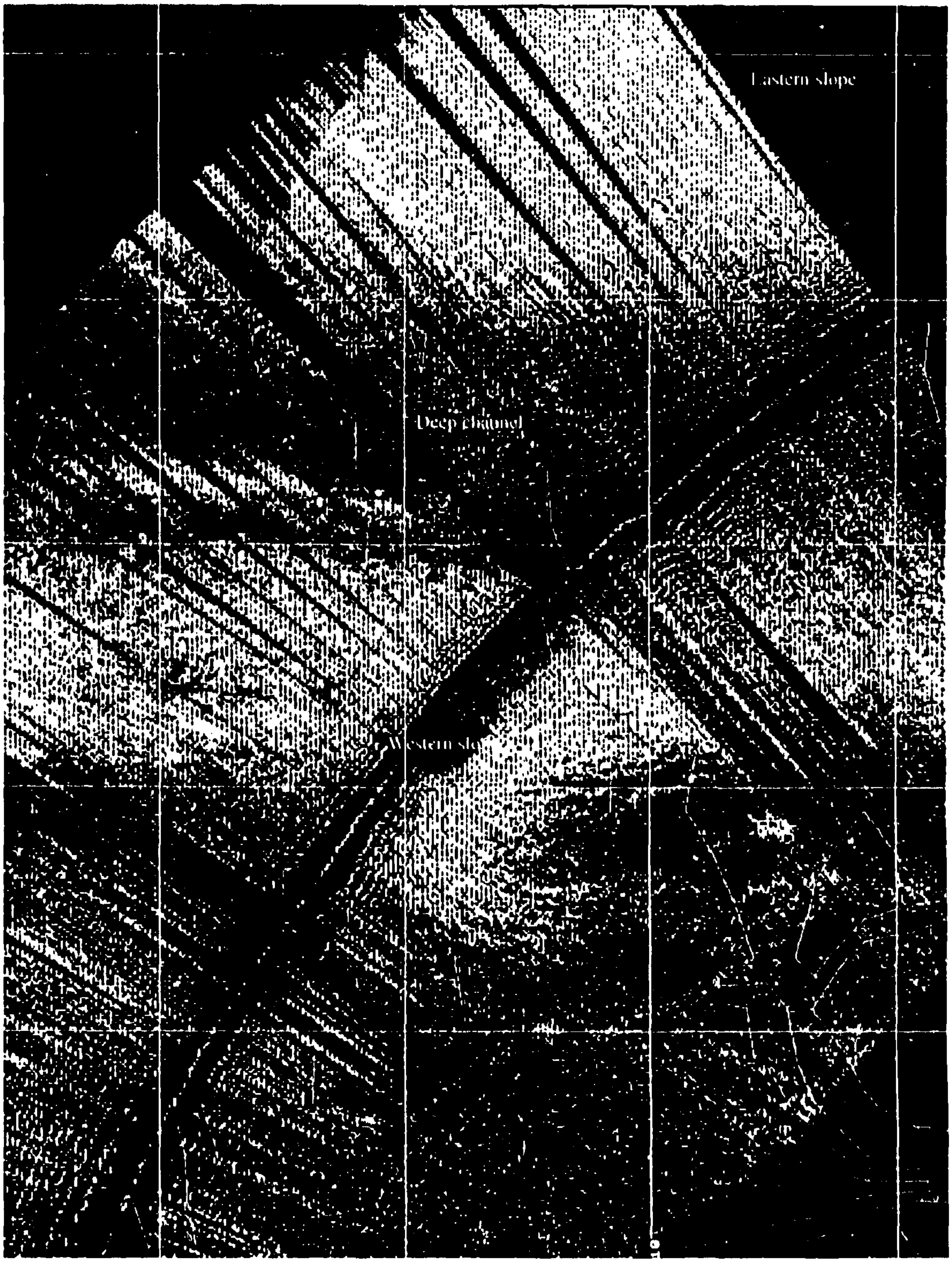


Figure 38. Mosaic of deep Susquehanna River thalweg

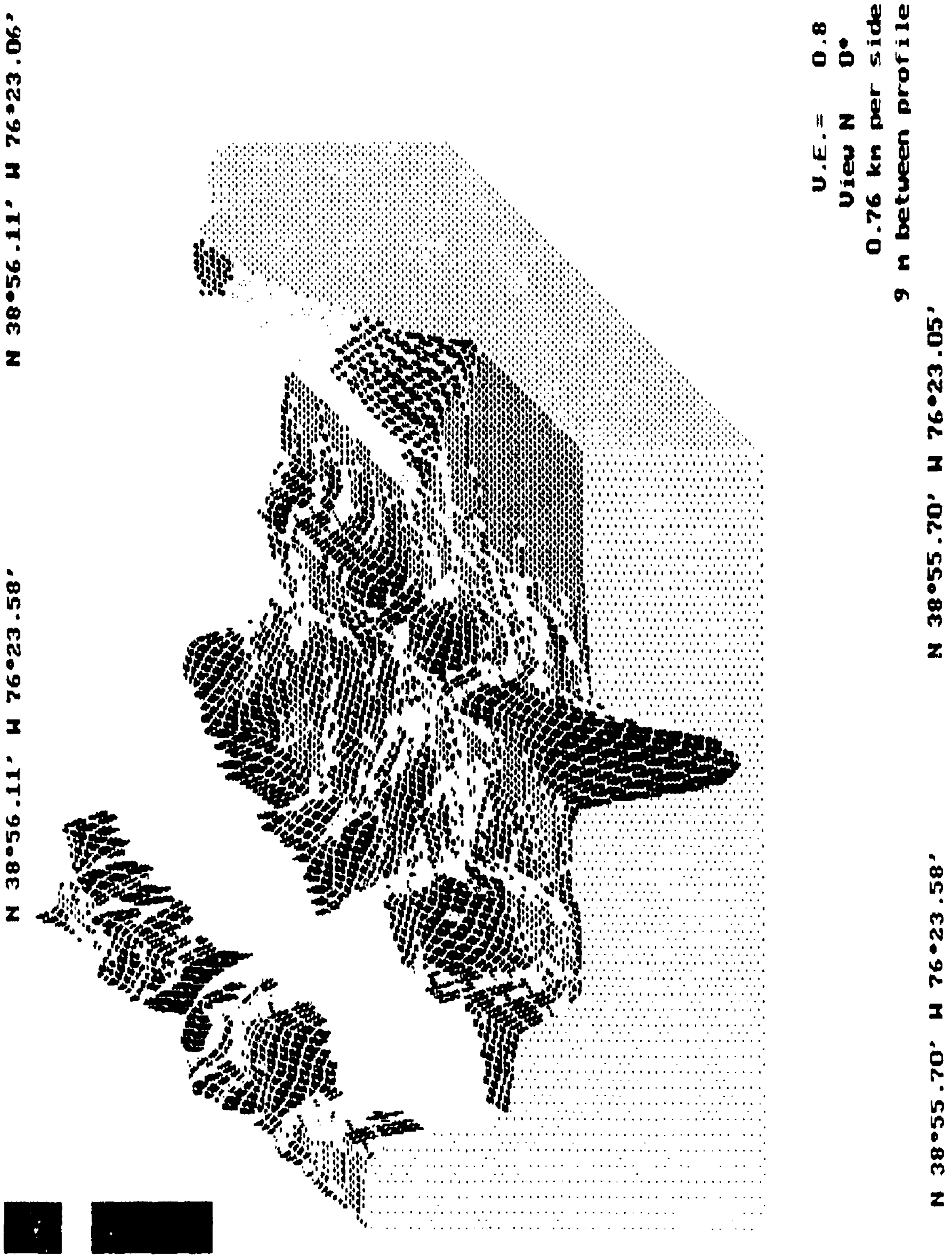


Figure 39. Oblique view of the deep thalweg

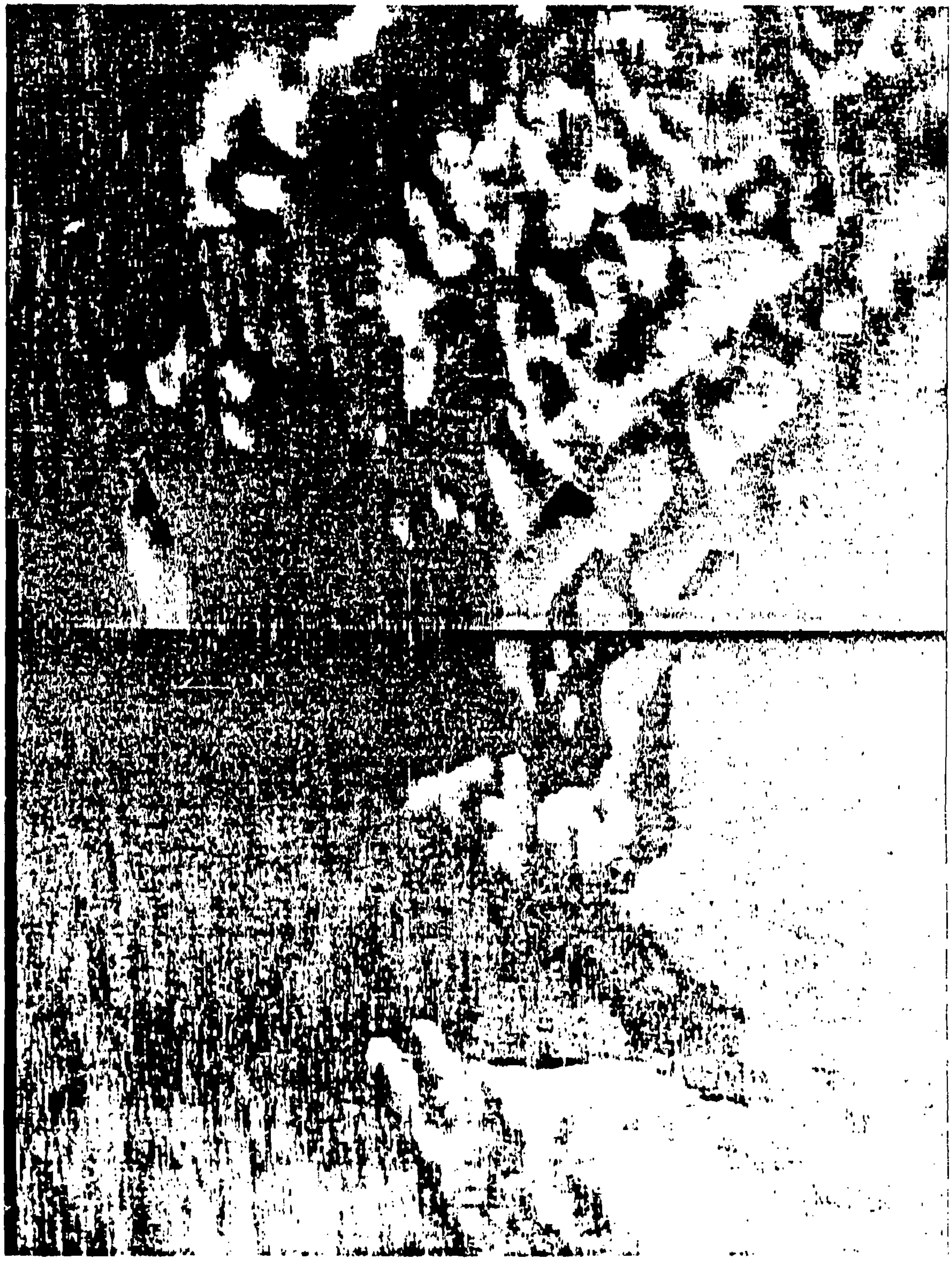


Figure 40. There is a distinct difference between oyster and mud reflectances, as is shown in this image of the north edge of the Thomas Point oyster bar

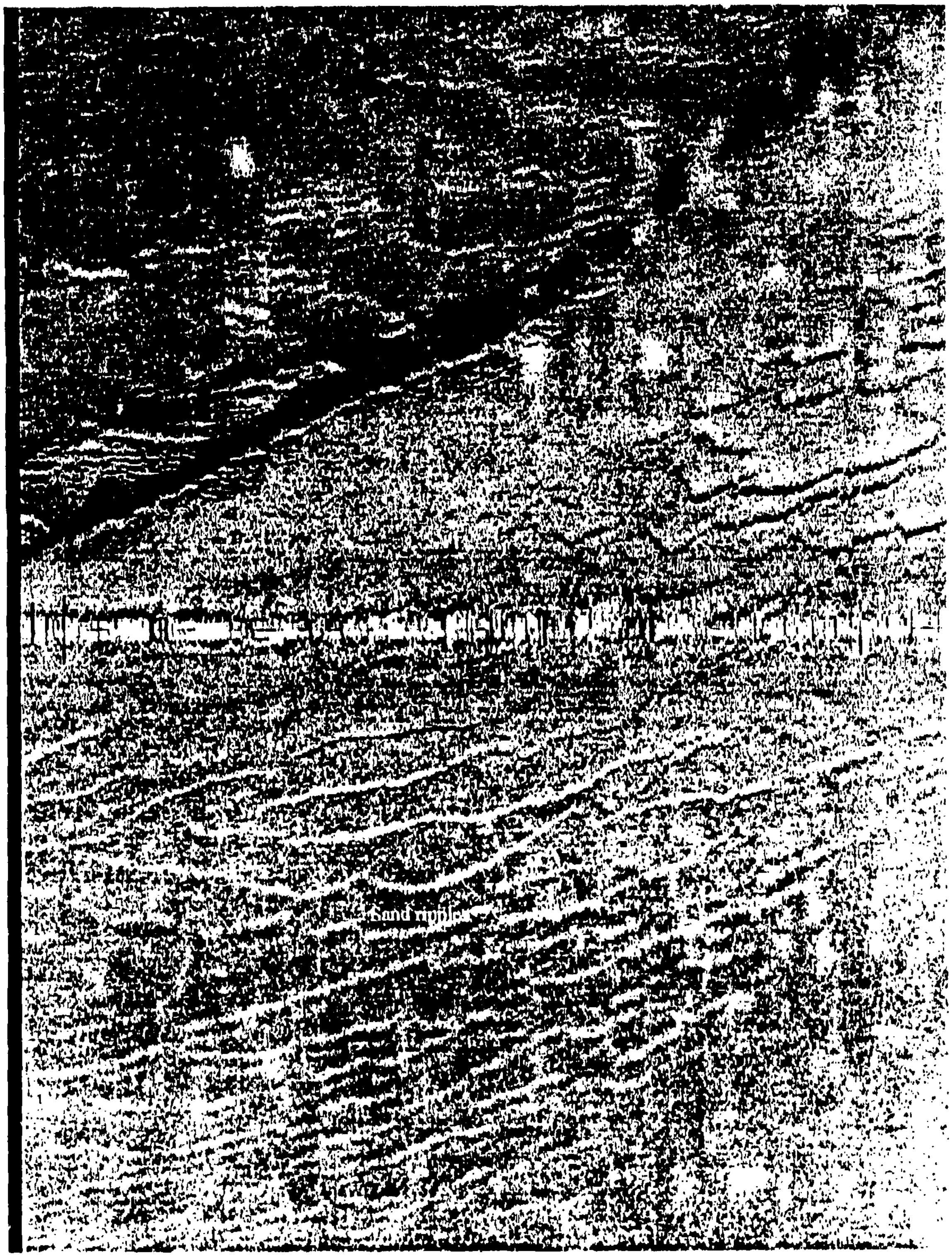


Figure 41. Reflectance of sandy bottoms falls in between that of oysters and mud. Sonograph from Delaware Bay.

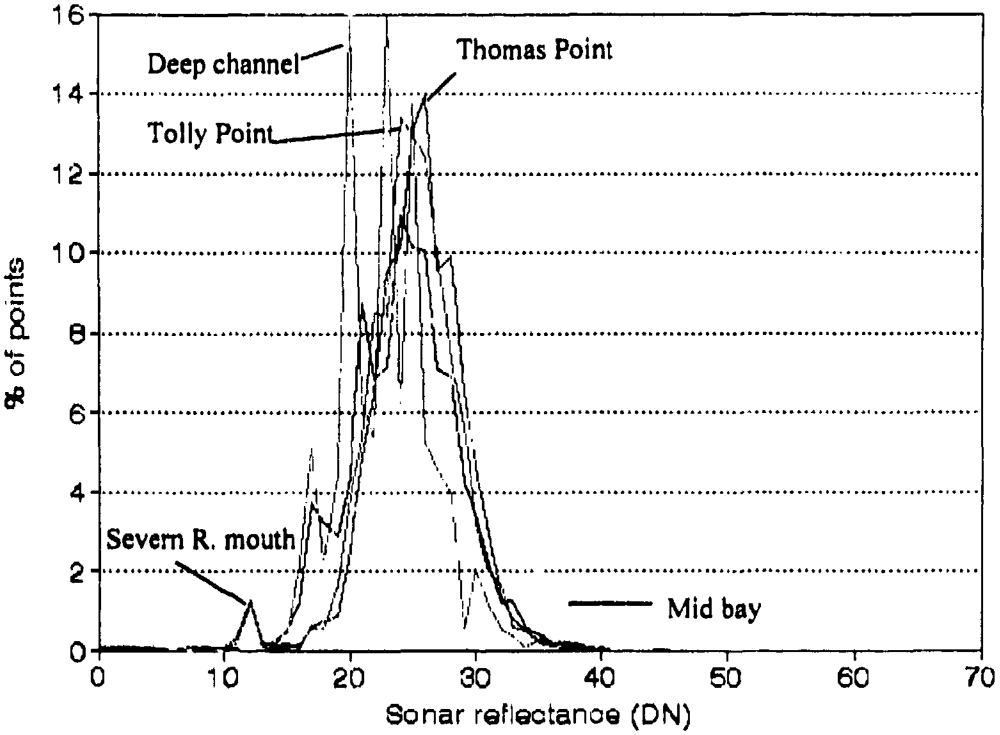


Figure 42. Mud reflectance histograms from all five study areas.

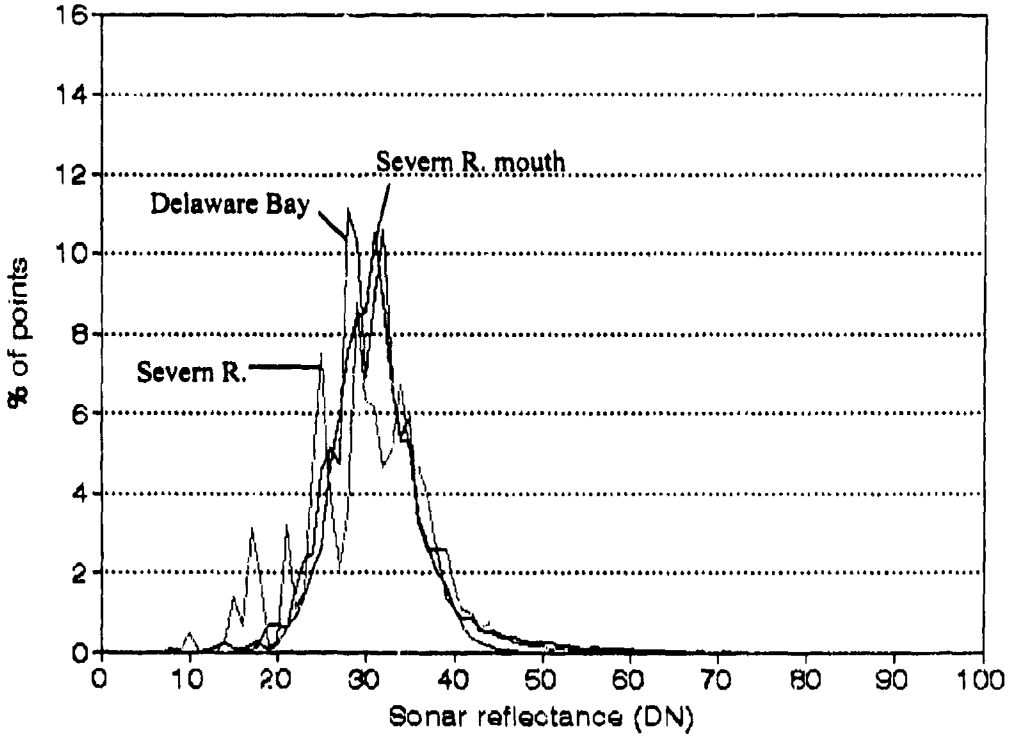


Figure 43. Sand reflectance histograms from Delaware Bay and the Severn River.

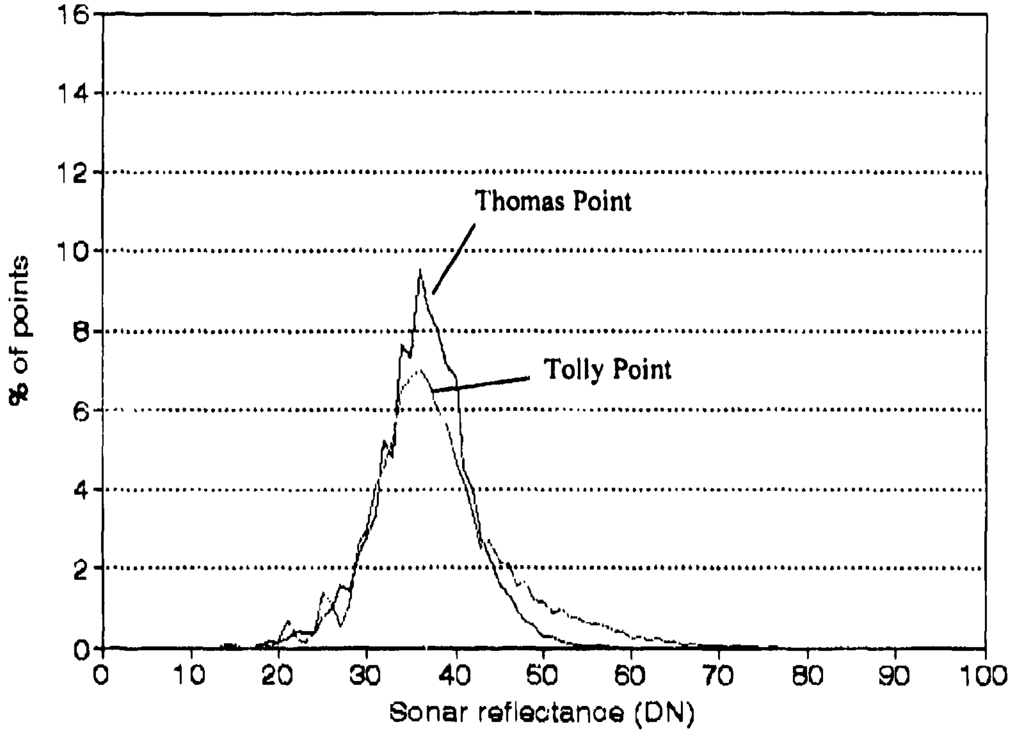


Figure 44. Oyster bar reflectance histograms from Tolly and Thomas Points.

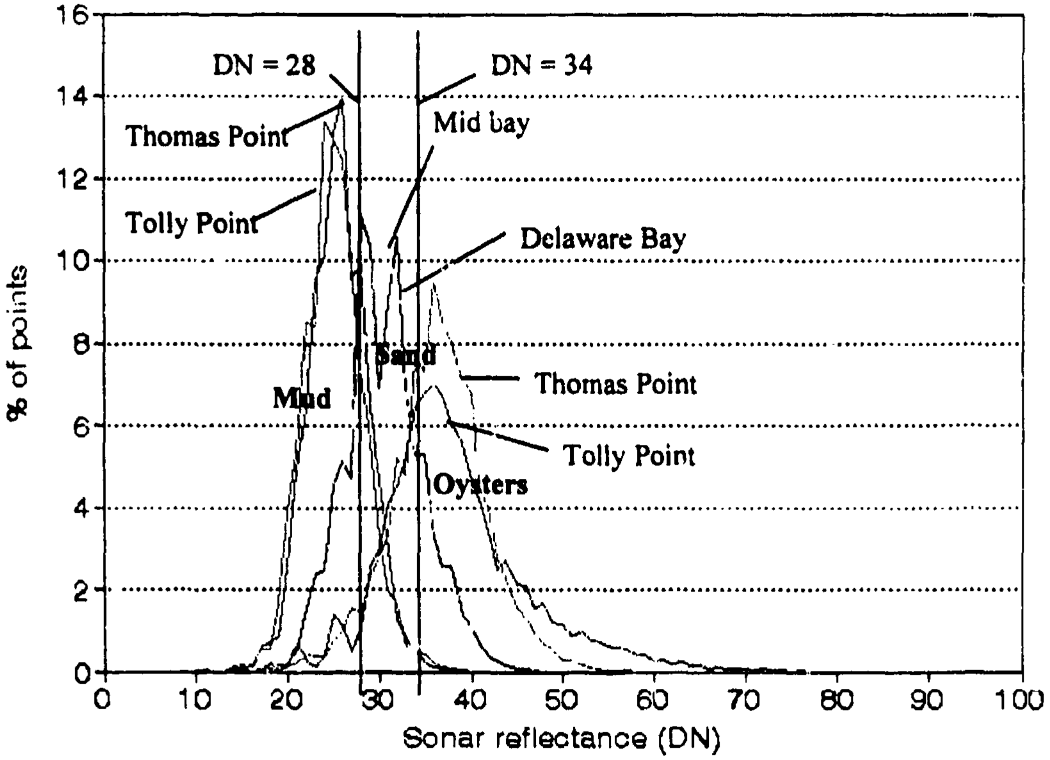


Figure 45. Histogram comparison of three general sediment types.

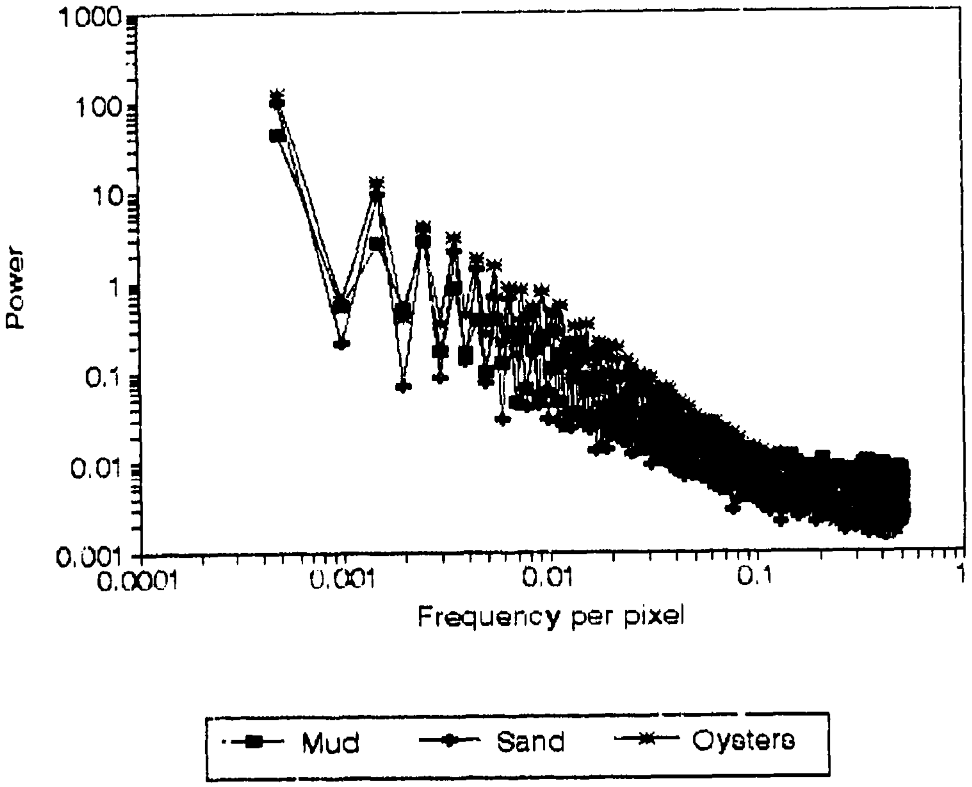


Figure 46. Fast fourier transforms of mud, sand, and oyster images yielded this power spectra distribution.

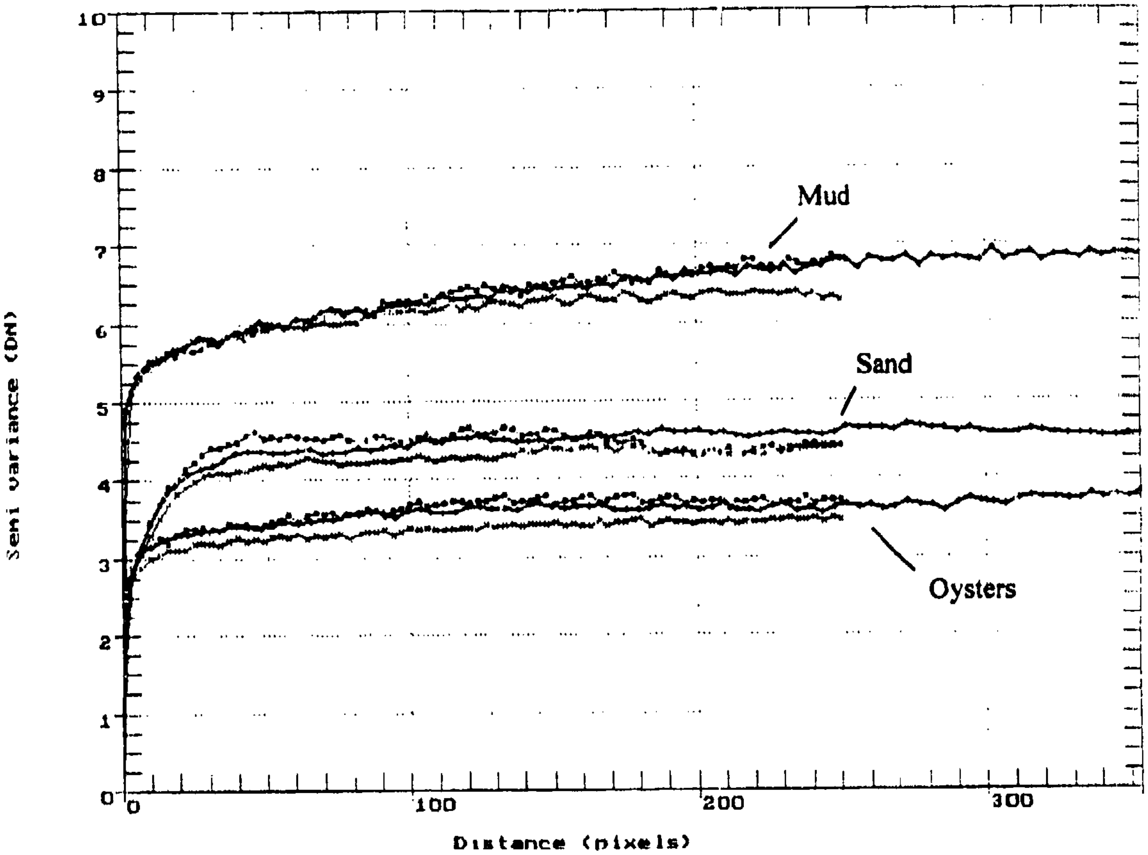


Figure 47. Semivariogram of spatial correlation of mud, sand, and oysters. The four curves for each sediment type represent the directions (N-S, E-W, NE-SW, NW-SE) sampled. The small deviations between direction curves indicate isotropic data sets.

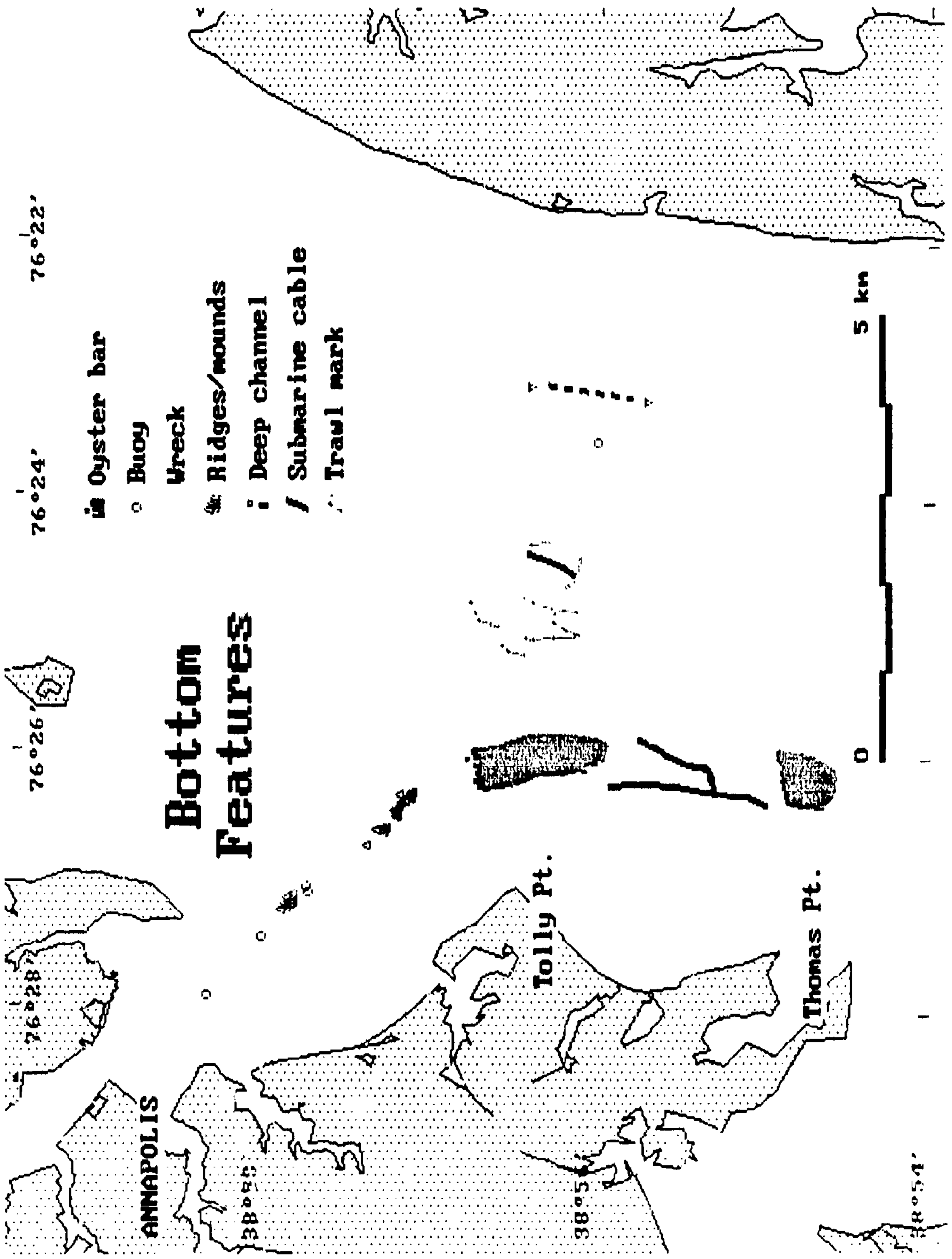


Figure 48. Summary of bottom features identified with side-scan sonar.

Figure 49. Two buoys in the Severn River.

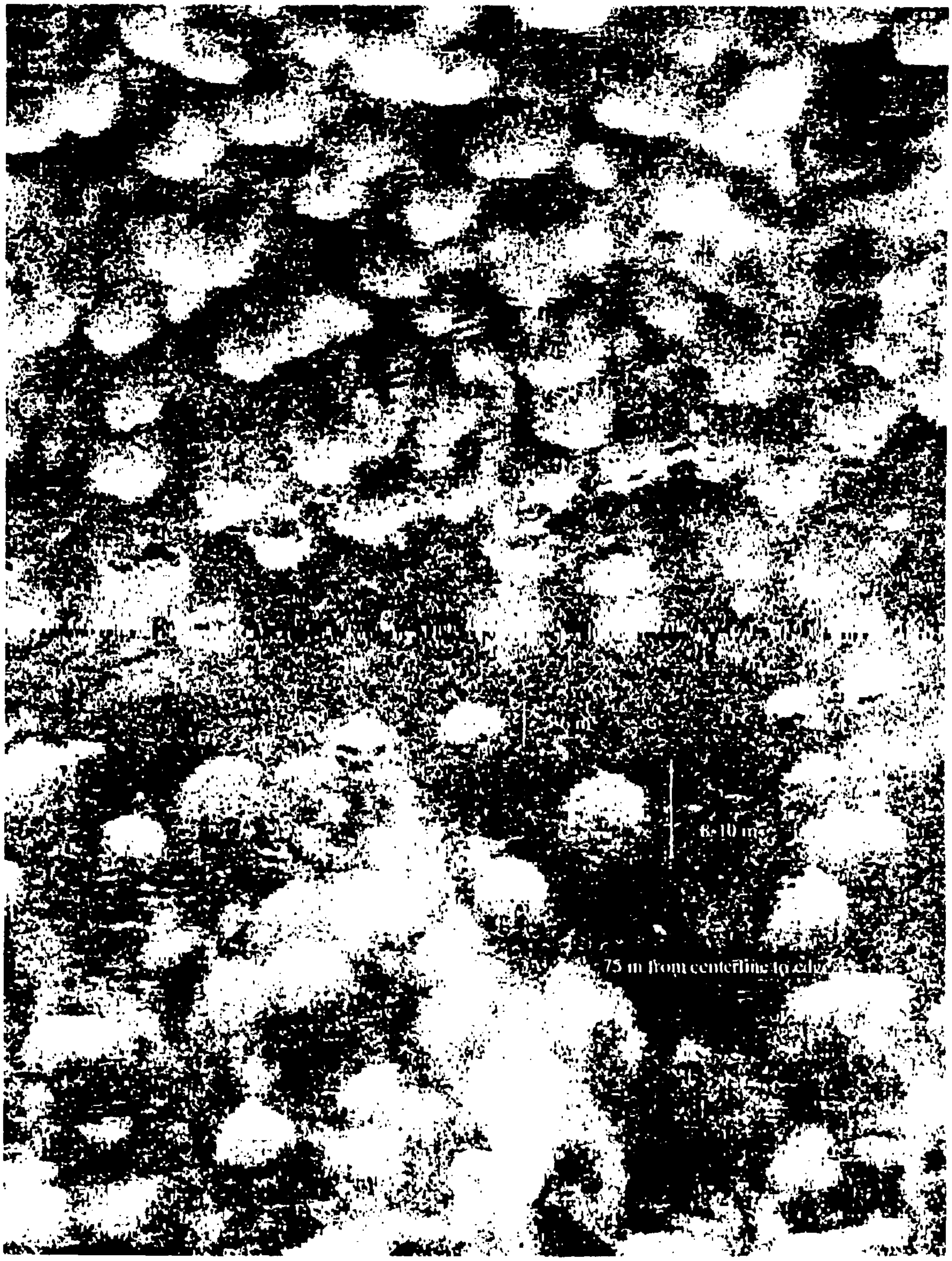


Figure 50. Circular mounds in the Severn River.

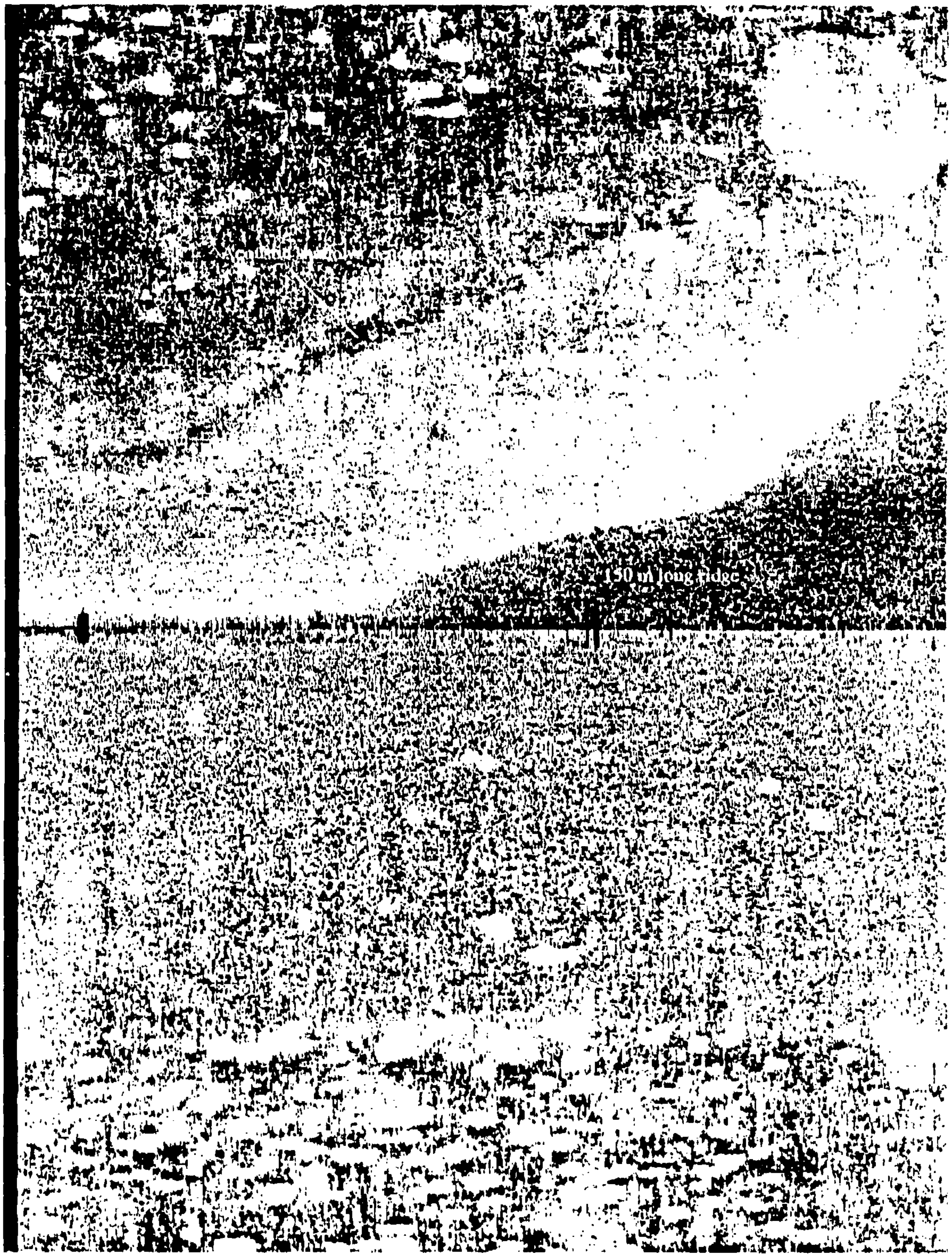


Figure 51. Ridges and mounds in the Severn River mouth

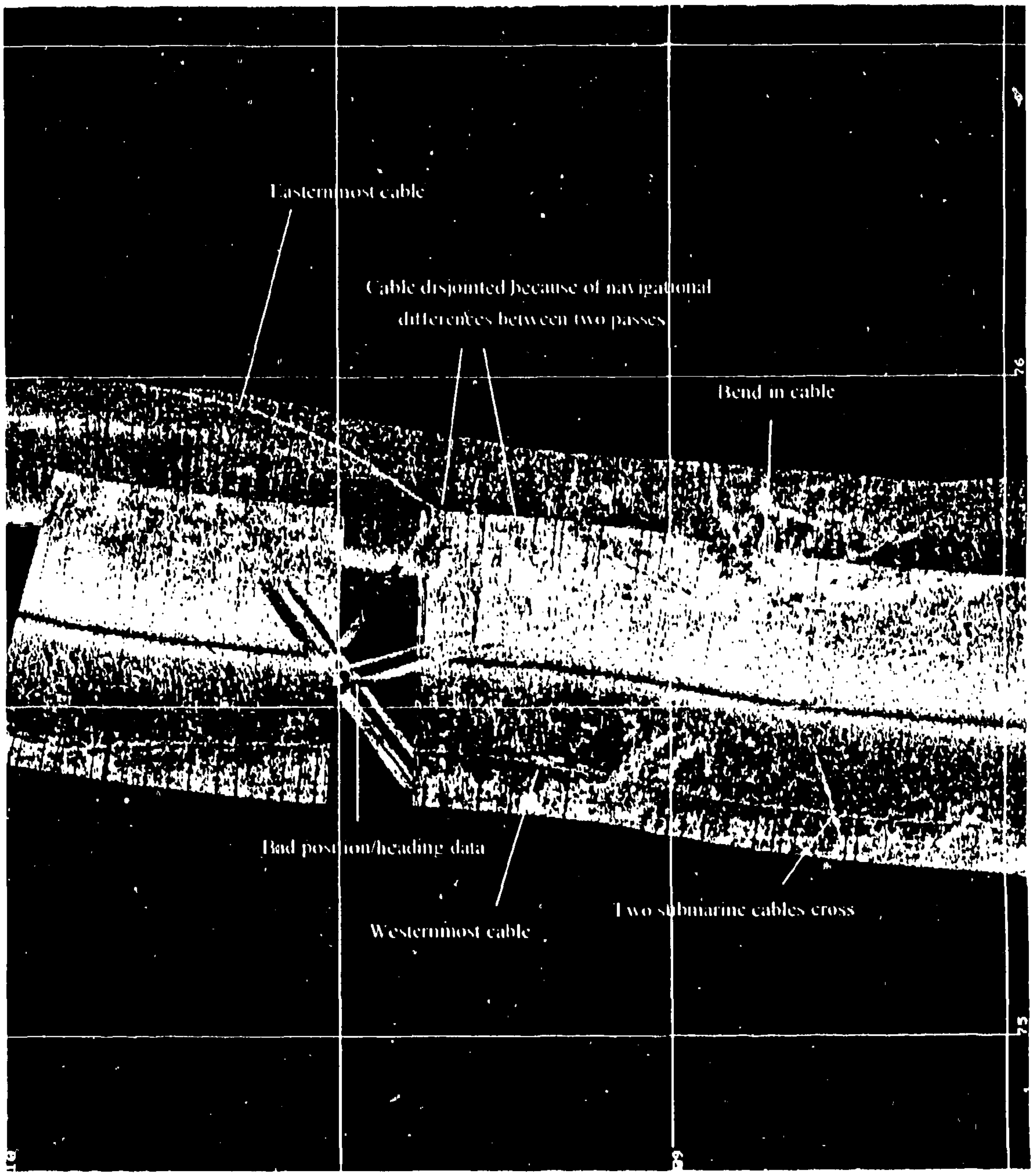

Easternmost cable
Cable disjointed because of navigational
differences between two passes
Bend in cable
Bad position/heading data
Westernmost cable
Two submarine cables cross
76
75
69

Figure 52. Two submarine cables located between Tolly and Thomas Points

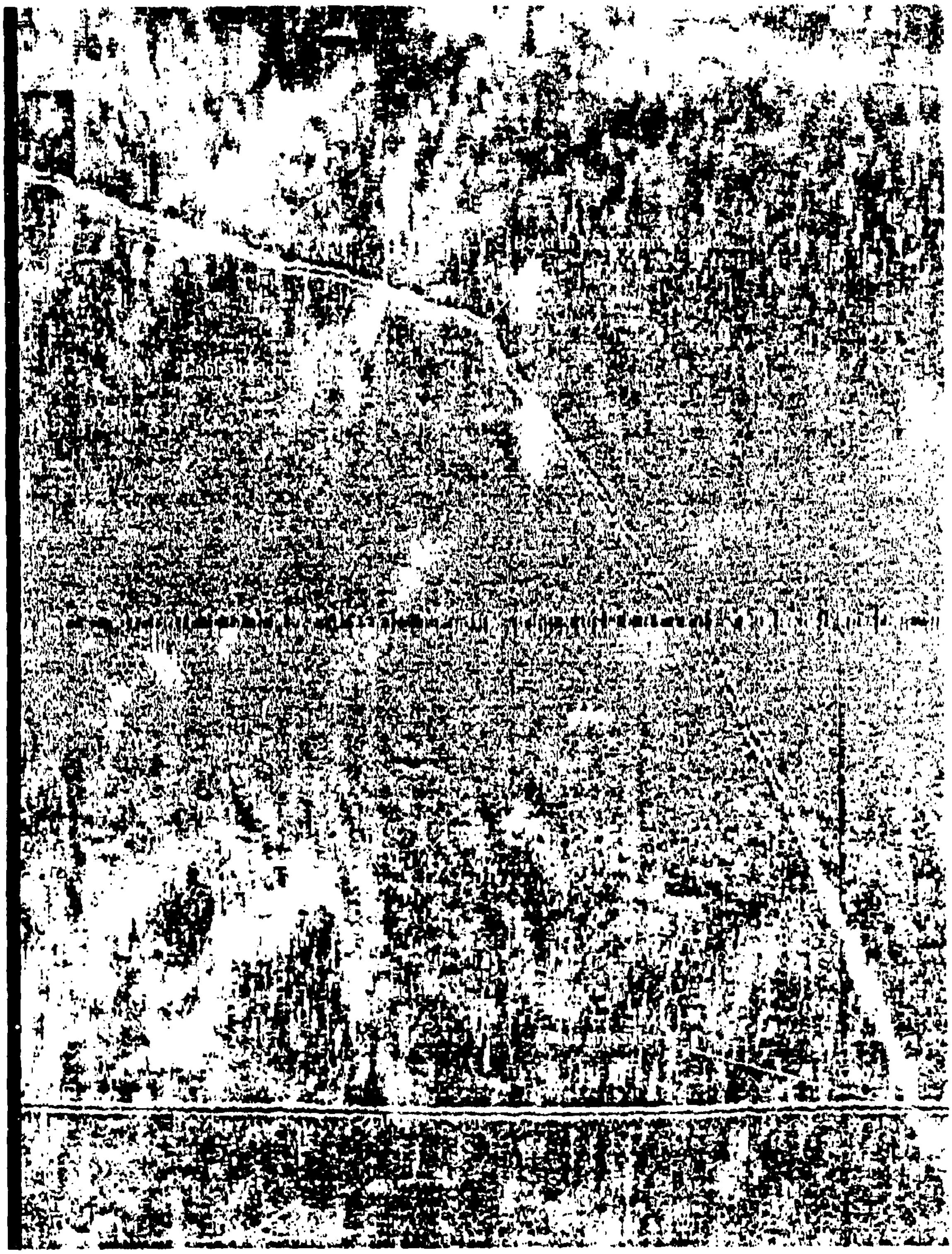


Figure 53. Detail of submarine cable intersection.

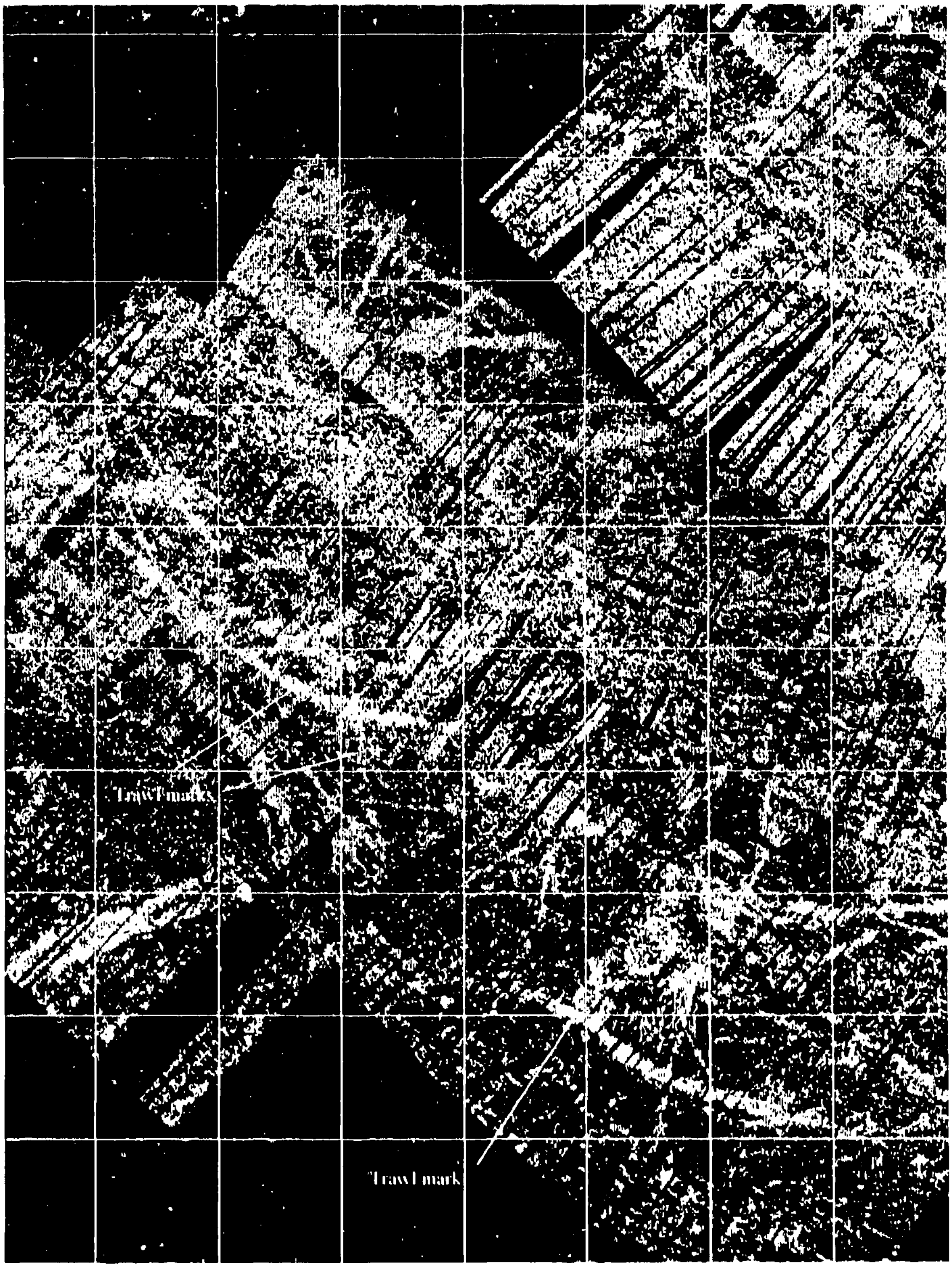


Figure 54. Trawl or scour marks in the mid Chesapeake Bay

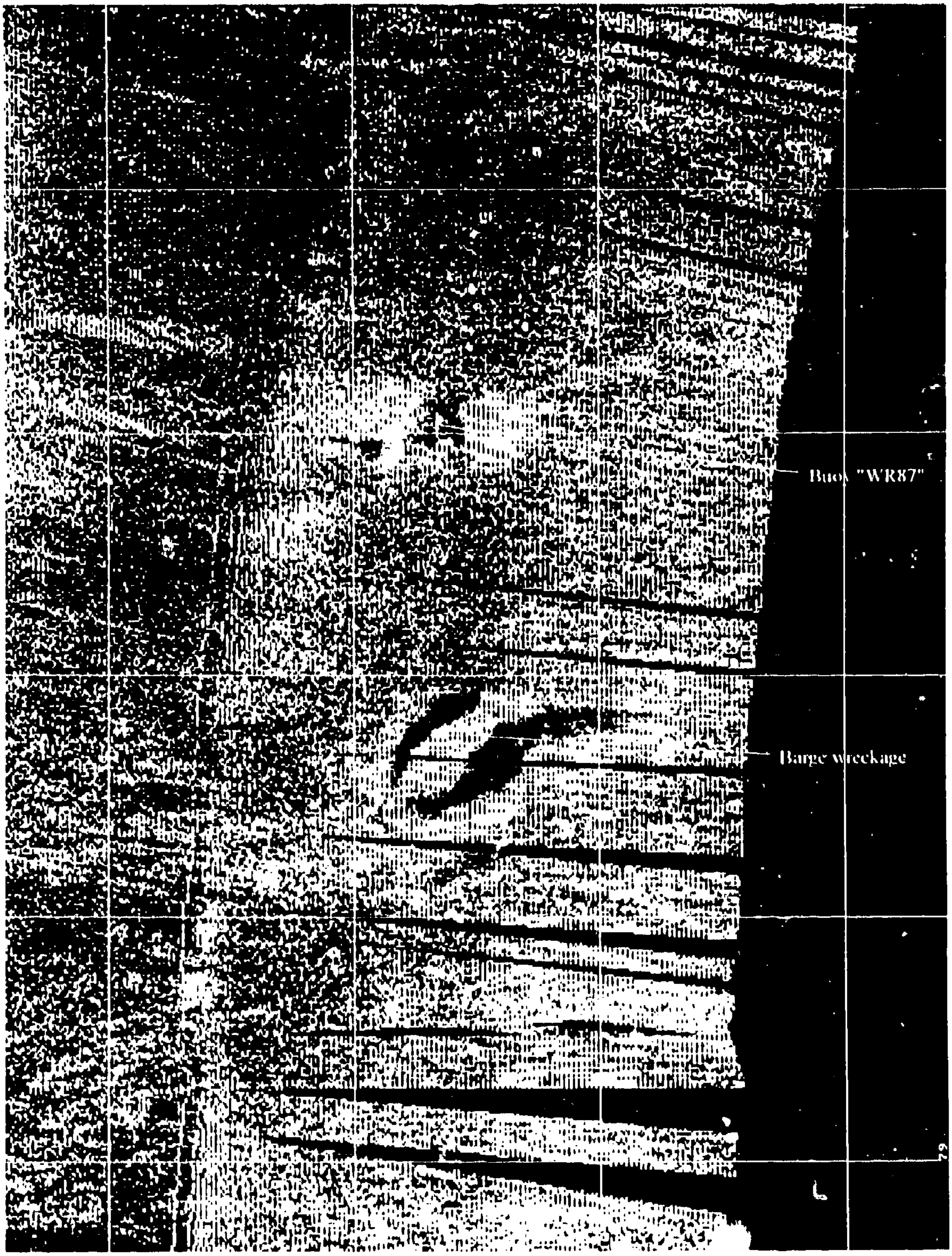


Figure 55. Mosaic of barge wreckage and warning buoy "WR87" showing their proper spatial orientation

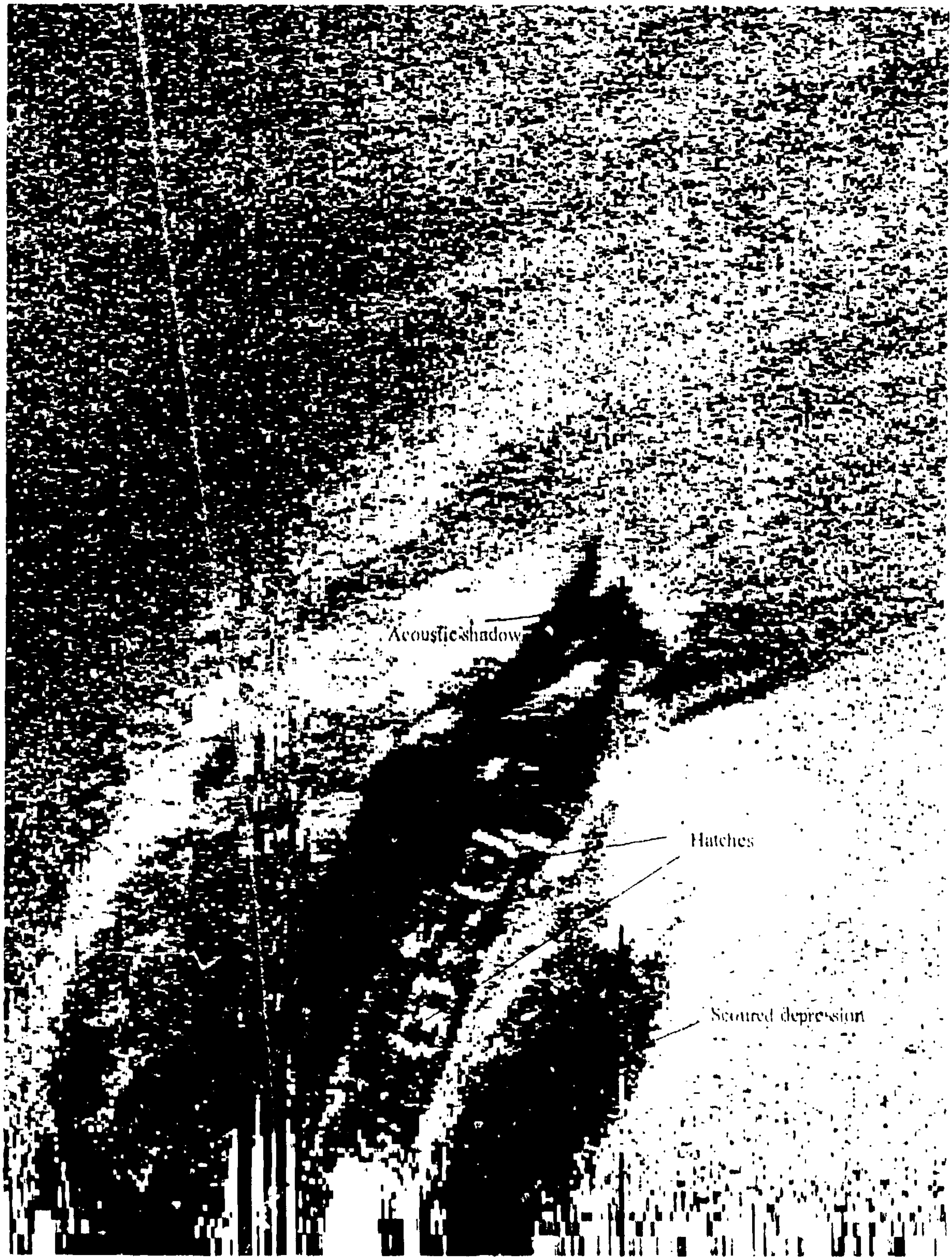


Figure 56. Detail of barge wreckage. Two rectangular hatches can clearly be seen

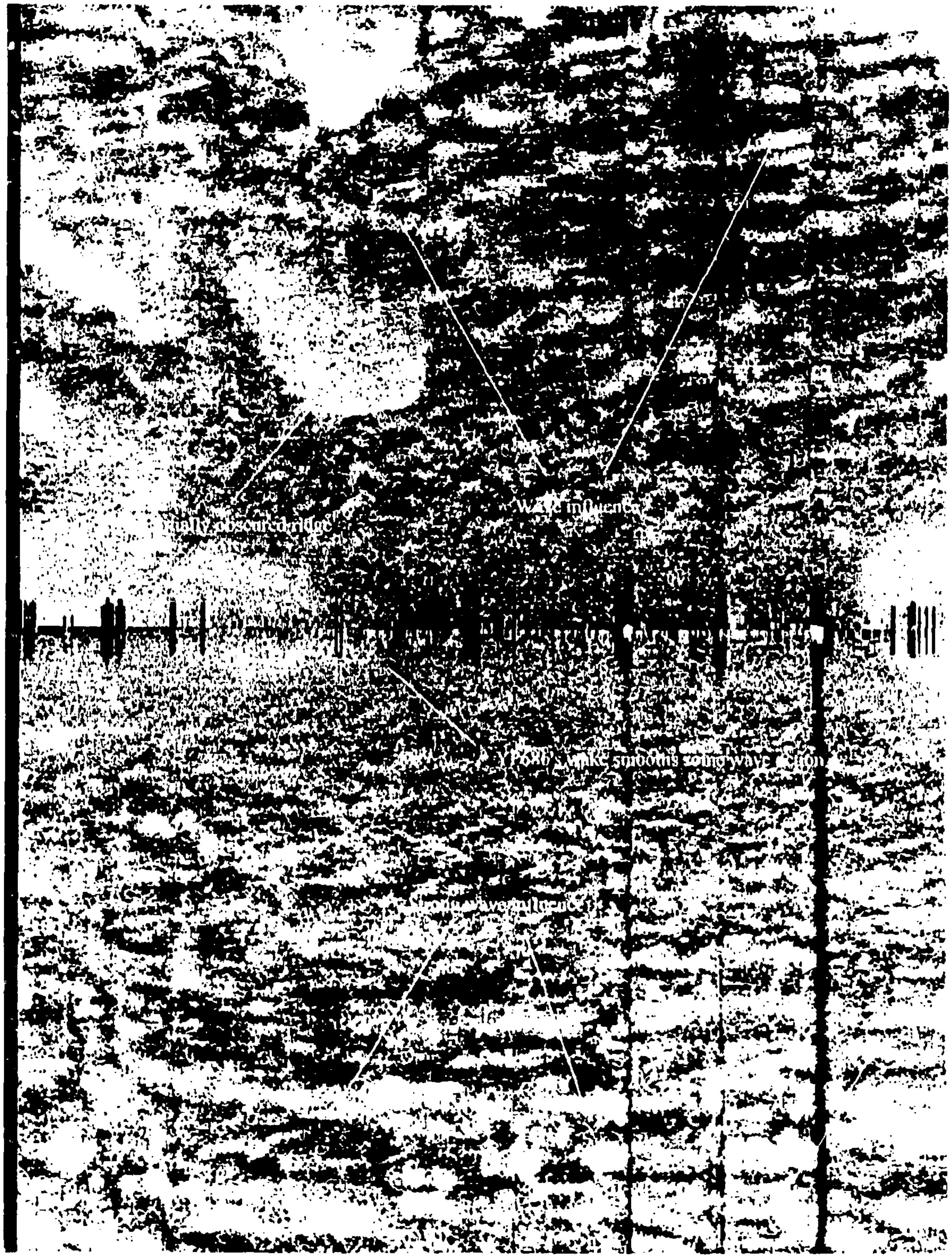


Figure 57. Surface wave action in the Severn River visible as high energy interference

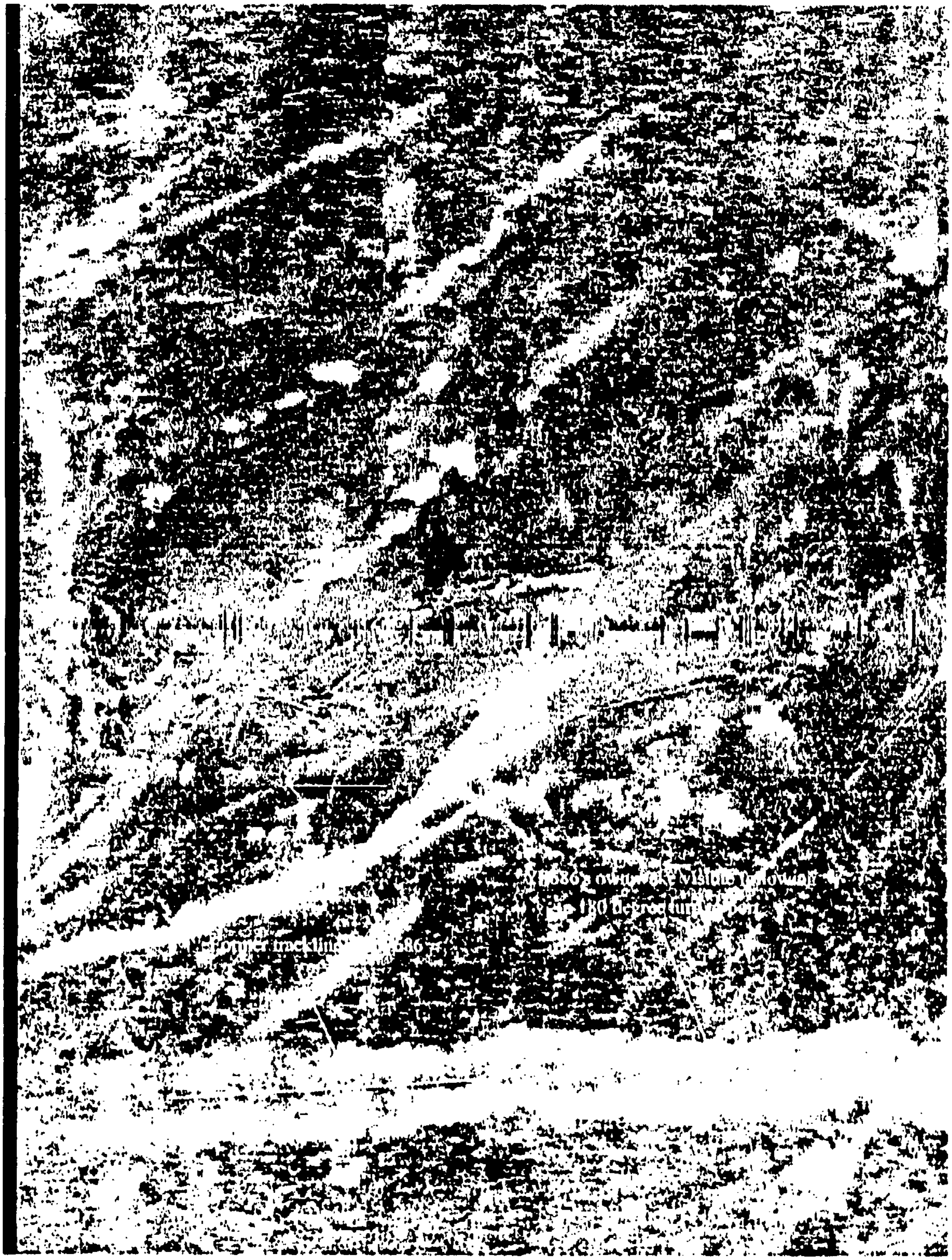

YP686's own wake visible following
a 180 degree turn to port
Former trackline of YP686

Figure 58. Wakes are visible up to 5 minutes after vessel passage because propellers mix air bubbles into the water column, increasing its acoustic reflectance.

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Appendices

A. Using SIDESCAN

SIDESCAN allows the user to manipulate side-scan data so that the most useful images are produced. The following steps allow the user to take full advantage of SIDESCAN's capabilities.

1. Data collection

- Write side-scan data to to 8mm digital tape while collecting
- Write GPS position and EchoTrac depth soundings to microcomputer file
- Several times during the trip, note the exact time difference between the EG&G time counter and the GPS
- Although it is not essential, try to record the EG&G times when the survey vessel was turning

2. Image rectification

- Use the NOVA conversion software to convert 8mm data to a DOS file
- Copy the .HYD file from the data run to the hard drive
- Enter SIDESCAN and select 'Create subset'
- Select a beginning record number and number of records to copy; limit this to no more than 2500 and try to exclude turns (based on EG&G times)
- Select 'Ground register' from the main SIDESCAN menu
- Enter the time offset
- Select the .HYD file from the data collection day
- Choose a name for the output file
- Wait; computer will process file

3. Create registered image files

Single sonograph

- Select 'One sonograph'
- Pick the corrected sonograph file
- Choose 'Customize'
- Choose 'Copy to image file' and 'Radiometric corrections'
- 'Xit' from the customize menu and choose 'Both'
- Wait for image to display
- Select 'Resume' and 'N' to display again
- Select 'Image processing options'

Mosaic

- Select 'Make single mosaic'
- Select upper left corner in UTM coordinates
- Select channel and side-scan files to display/write to mosaic

4. Image enhancement:

- From main menu, select 'Image processing options'
- Select the MIDBAY DEM
- Graphically select or choose file name of image
- Select statistical options to suit user, including FFT, semivariogram, or bathymetric contour overlay

The following files are necessary to use all of the functions in SIDESCAN:

- SIDESCAN.EXE; the program
- RTM.EXE; protected mode interface (from *Borland International*)
- RTMRES.EXE; protected mode interface (from *Borland International*)

- DPMIMEM.DLL; protected mode interface (from *Borland International*)
- DPMI16BI.OVL; protected mode interface (from *Borland International*)
- DPMIINST.EXE; protected mode interface (from *Borland International*)
- DPMILOAD.EXE; protected mode interface (from *Borland International*)
- SVGA256.BGI; graphics interface for SVGA mode
- EGAVGA.BGI; graphics interface for VGA mode
- BGI256.BGI; graphics interface for SVGA mode
- OPSAREA.PRJ; UTM map projection
- OPSAREA.VGP; screen map
- MIDBAY.DEM; digital elevation model
- MIDBAY.HDR; DEM header with size and map projection information
- *.EGG; data files
- *.HYD; hydrographic files
- *.MIC; sediment sample ASCII data files
- *.FIL; filters
- *.HLP; help files

B. SIDESCAN Help Files

These are the text files which accompany almost every menu in SIDESCAN. They can be displayed by typing 'F1' while in SIDESCAN.

Main Menu

DISPLAY:

One sonograph - displays one geometrically corrected sonograph according to the user's specifications.

Multiple sonographs - displays two or three corrected sonographs side by side.

Altitude distribution - displays the average fish height off the bottom, based on the first bottom return. as a function of distance from the fish.

Digital mosaic - allows user to merge fully corrected side-scan data files onto a single projection, displaying each data point at its actual ground location. Also allows user to combine previously created mosaics.

Frequency distribution - displays the average return strength (of a selected record) of the sonar versus distance from the nadir of the towfish.

Profile across track - allows user to display return strengths from single side-scan records.

OPTIONS:

Create EGG subset - allows user to create a smaller EG&G side-scan file from a large original. Useful when used in conjunction with the 'Ground register' feature.

Ground register - merges an unprocessed EG&G file with an .HYD file from the same date. The .HYD file is filtered and headings and UTM coordinates for the centerline of the EG&G file written to the EG&G data blocks. Make sure that there is enough virtual disk space to compensate for the size of the EG&G file - it will be temporarily written there.

Hydrographic options - calls the 'GPS survey' procedure, which allows one to plot GPS data files and manipulate projections.

Image processing options - calls the 'Satellite Image' procedure from MICRODEM. This is useful in displaying processed full-length image files on a single screen and merging them with digital bathymetric data of the operating area. Statistical operations can also be performed here.

Sediment analysis - calls the 'sieve' procedure. It is used for the analysis of the GALAI CIS-100 particle size analysis data. It allows the user to graphically pick the bottom grab station, and will plot the sample on both a tertiary diagram and cumulative weight % versus grain size in mm plot.

Sonograph Display

CHANNEL DISPLAYED:

Port - displays only the port channel of the sonograph at the desired settings. Recommended for better detail of the port channel.

Starboard - displays only the starboard channel of the sonograph at the desired settings. Recommended for higher detail of the starboard channel.

Both - displays both the port and starboard channels of a given sonograph at the desired settings. Recommended for standard viewing

DISPLAY PREFERENCES:

Express - automatically sets the options permitting the fastest possible viewing speed.

Customize - allows user to modify the display options to suit his/her viewing needs.

Abort - aborts the display function and returns user to the main menu.

Customize Options

MODIFY PREFERENCES:

Bottom tracking, channel - the port, starboard, or an average of both channels may be used to determine the height of the towfish above the bottom. First time users should use the Altitude Distribution function to determine which channel produces the most consistent fish height.

Copy to image file - while displaying the data to the screen, the program also copies the data to a file which can be analyzed using standard image processing software (see main menu - Image processing options). It also writes .IDX and .XY files, containing the indexing information and UTM coordinates of the four corners of the image, respectively.

Display status bar - turns on or off the status bar, which contains the following information: file name, time, record number, speed, range, frequency, and heading.

Edit bottomvalue, x - allows the user to specify the value which the computer assumes to be the value of the first bottom return. For deep water, the bottomvalue should be decreased because of the increased attenuation. The opposite is true of especially shallow runs. User is encouraged to use the Frequency Distribution or Altitude Distribution functions to determine what value produces the most accurate fish height.

Invert - scrolls the image down from the top of the screen, instead of vice versa. This is useful when combined with the Multiple sonographs display choice and two images which are parallel and adjacent. Inverting one of the images allows the images to be compared with similar geometric orientation.

Number of columns to display, x - specifies the number of columns to subdivide the screen into when displaying. Useful when a user wants to examine a large image on one screen.

Radiometric corrections - at the sacrifice of display speed, this algorithm averages the columns for the entire record and applies a radiometric averaging function which alleviates the far range power drop off.

Target color - switches the colors associated with strong and weak returns.

Wait when screen full - when selected, the program will wait until a key is pressed before clearing the screen and scrolling more data. When unselected, the program continuously scrolls the data.

Xit - exits the menu and returns to the CHANNEL DISPLAYED menu.

Sonograph Display (while displaying)

IMAGE OPTIONS:

Resume - resumes display of the data from where the program left off. Also, this should be chosen after displaying a record while Copying to image file, if this option is selected as a preference.

Image - user can restore, save, or modify a displayed image in a variety of formats.

Get position - using the mouse, the user can get the UTM coordinates and latitude/longitude of any selected point on the record. Note that the record MUST BE ground registered (see main menu) for this to work. An easy way to tell if the image IS ground registered is to observe the heading Uncorrected images will display a constant heading of 0.

Measure distance - similar to the Get position function, except two points must be selected. The distance between the two points will be computed.

DISPLAY PREFERENCES:

Express - automatically sets the options permitting the fastest possible viewing speed.

Customize - allows user to modify the display options to suit his/her viewing needs.

Abort - terminates the display. The user will have the option to display the same image or return to the main menu.

Customize Options (while displaying)

MODIFY PREFERENCES:

Bottom tracking, channel - the port, starboard, or an average of both channels may be used to determine the height of the towfish above the bottom. First time users should use the Altitude Distribution function to determine which channel produces the most consistent fish height.

Display status bar - turns on or off the status bar, which contains the following information: file name, time, record number, speed, range, frequency, and heading.

Edit bottomvalue, x - allows the user to specify the value which the computer assumes to be the value of the first bottom return. For deep water, the bottomvalue should be decreased because of the increased attenuation. The opposite is true of especially shallow runs. User is encouraged to use the Frequency Distribution or Altitude Distribution functions to determine what constant produces the most consistent fish height.

LUT recalculations skipped - for the fastest possible viewing, this feature aborts the recalculation of lookup tables for slant range correction if the fish height deviates beyond a certain value (essentially, if this is selected, the same LUT is used for the whole image, irregardless of fish height).

Radiometric corrections - this algorithm averages the columns and writes them to a .CTA text file (or reads the values from the .CTA file, if it exists) for the entire record. Then, at the sacrifice of display speed, the program applies a radiometric averaging function to each pixel which alleviates the far range power drop off.

Target color - switches the colors associated with strong and weak returns.

Wait when screen full - when selected, the program will wait until a key is pressed before clearing the screen and scrolling more data. When unselected, the program continuously scrolls the data.

Xit - exits the menu and returns to the IMAGE OPTIONS menu.

Digital mosaic options

OPTIONS:

Make single mosaic - user may write port, starboard, or both channels of selected side-scan data files onto a projection. User must select the x and y utm coordinates of the upper left hand corner of the mosaic box. The data is displayed in their real ground locations, and digital numbers of data are radiometrically corrected.

Combine existing mosaics - mosaics with the same upper left corner values created with the previous function may be combined into a single comprehensive image.

C. SIDESCAN Borland Pascal Code

```
{$F+,O+}

unit SIDESCAN;

  {$Define WriteOutPut}

interface

  Procedure SideScanOps;

implementation

uses
  PETDef,PETMAR,PETOver,PETGraph,PETMath,Dipstrike,Mapproj,SievMain,   {Prof. Guth's units}
  DrawMain,DEMEROS,DEMEROS2,   {Prof. Guth's units}
  Graph,CRT,DOS;  {Borland International units}


type
  StdRecType = array[0..1799] of byte;
  SideScanDefaultType = record
    DataPath : PathStr;
  end;
  ProjectionProcedure = procedure(Lat,Long,Elev : float;
     Size,Color : integer; Sym : DrawingSymbol);
  PositionType = record
    TimeStr  : string12;
    Lat,Long : float;
  end;
  HydroSurveyPositionType = record
    Position : PositionType;
    Depth    : integer;
  end;

var
  SideScanDefaults : SideScanDefaultType;
  DefaultsFile : file of SideScanDefaultType;
  DataFile,COutFile : file of StdRecType;
  ImageFile : file;
  JunkFile,IndexFile,XYFile,RadioFile : text;
  StdRec : StdRecType;
  ColorTable : ColorTableType;
  Freq : array[0..255] of LongInt;
  AvgPrt,AvgStd : array[0..883] of float;
  ColorBytes : array[0..255] of byte;
  OutVal : array[0..MaxScreenXMax] of byte;
  ScreenLUT : array[0..MaxScreenXMax] of integer;
  NormalColor,WaitAtBottom,GPSDepthMode,UseProject,Done,Invert,RepeatRow,CopyImage,FileOpen,
  Starboard : boolean;
  ch,PortCh,DispCh,BottomChannel : char;
  Sym : DrawingSymbol;
  Dir : DirStr;
  Name : NameStr;
  Ext : ExtStr;
  PixelDist,SpeedInterval,Remainder,SumRemainder,TrueDist,SlantDist,SlantTime,Lat,Long,
  Speed,Heading,Range,DistFromCent,FishHt1,FishHt2,FishHeight,OldHt1,OldHt2,DevFishHeight : float;
  NumGrays,Offset,Max,Factor,ColSkip,i,j,x,y,counter,NumPixelsShow,YSpacer,SpeedYSpacer,
  TempMapX,TempMapy,Temp2MapX,Temp2Mapy,NumHorizCycles,NumVertCycles,StartPort,StartStar,
  TransmitPeriod,ScreensDone,ColsSidebySide,ColsDone,XDeflection,BeginVal,Size,Color,DepthLimit,
  RecXMax,LUTInc,OneOrBoth,BotVal : integer;
  FreqUsed,StartRecord,OnRecord,ResumeMarker,NumRec,NumRecs,RowCounter,ZeroXOffset,
  ZeroYOffset : LongInt;
  HorizCycleCuts,VertCycleCuts  : CycleCutType;
  FName,DataSubDir,DataPath,CFilename : pathstr;
  ProjectProc : ProjectionProcedure;
  xw,yw,YDesired,XDesired : word;
  xutm,yutm,Finalxutm,Finalyutm,Final2xutm,Final2yutm,Centxutm,Centyutm,PointDist : shortfloat;
  TimeString : string8;


procedure UTMInitialize;

var
  ProjFileName : string;

begin
  ProjFileName := SideScanDefaults.Datapath + 'opsarea.prj';
  if ProjFileName = '' then exit else ReadProjection(ProjFileName);
  if Projection.Pname <> UTMEllipsoidal then
    MessageToContinueXY(1,1,'Not UTM projection: problems likely.');
end;

{$I side-hyd.pas} {Prof. Guth's hydrographic survey routine}

procedure AnalyzeRecord;

var
  i : integer;

begin
  for i := 0 to 17 do dec(StdRec[i],128);
    TimeString := IntegerToString(StdRec[3],2) + ':' +
              IntegerToString(StdRec[2],2) + ':' +
              IntegerToString(StdRec[1],2);
  for i := 2 to 8 do if TimeString[i] = ' ' then TimeString[i] := '0';
  Speed := StdRec[12] * 10 + StdRec[11] * 0.1;
  Range := StdRec[17] * 100 + StdRec[16];
  Heading := StdRec[14] * 100 + StdRec[13];
  case round(Range) of
    25,50 : TransmitPeriod := 75;
    75 : TransmitPeriod := 113;
    100 : TransmitPeriod := 150;
    150 : TransmitPeriod := 225;
    200 : TransmitPeriod := 300;
    300 : TransmitPeriod := 450;
    400 : TransmitPeriod := 600;
    600 : TransmitPeriod := 900;
  end;
  Move(StdRec[19],xutm,4);
  Move(StdRec[23],yutm,4);
  if (StdRec[15] and 64 = 64) then FreqUsed := 500 else FreqUsed := 100;
end;
```

```
function ChannelName(Ch:char):string12;

begin
  case Ch of
    'P' : ChannelName := 'Port';
    'S' : ChannelName := 'Starboard';
    'B' : ChannelName := 'Both';
  end;
end;


procedure FindFishHeight(var Bottomstart:integer);

var
  x1,x2 : integer;
  MaxVal : integer;

begin
  RepeatRow := false;
  MaxVal := 60;
  x1 := 0;
  repeat
    inc(x1);
  until (x1 = 883) or ((StdRec[32 + 2 * x1] >= BotVal) and (StdRec[32 + 2 * x1] < MaxVal));
  if x1 = 883 then begin
    FishHt1 := OldHt1;
    RepeatRow := true;
  end;
  FishHt1 := 1.0 * x1 * TransmitPeriod / 883 * 1500 * 0.001 * 0.5;
  OldHt1 := FishHt1;
  x2 := 0;
  repeat
    inc(x2);
  until (x2 = 883) or ((StdRec[33 + 2 * x2] >= BotVal) and (StdRec[32 + 2 * x1] < MaxVal));
  if x2 = 883 then begin
    FishHt2 := OldHt2;
    RepeatRow := true;
  end;
  FishHt2 := 1.0 * x2 * TransmitPeriod / 883 * 1500 * 0.001 * 0.5;
  OldHt2 := FishHt2;
  case BottomChannel of
    'P' : begin
            FishHeight := FishHt1;
            BottomStart := x1;
          end;
    'S' : begin
            FishHeight := FishHt2;
            BottomStart := x2;
          end;
    'B' : begin
            FishHeight := 0.5 * (FishHt1 + FishHt2);
            BottomStart := (x1 + x2) div 2;
          end;
  end;
end;
```

```
procedure RadiometricCorrect;

var
  NewOutFile : file of StdRecType;
  Prt,Strboard,PrtCounter,StbdCounter: array[0..883] of Longint;
  PortTempRec,StbdTempRec : byte;
  ch : char;
  i,XCounter,BottomStart : integer;
  NumProc,Totalreturn : Longint;
  Filename : pathstr;
  Avgreturn : real;
  x,y,x1,x2 : word;

begin
  reset(DataFile);
  FSplit(FName,Dir,Name,ext);
  if FileisPresent(Dir + Name + '.cta') then begin
    assign(RadioFile,Dir + Name + '.cta');
    reset(RadioFile);
    for x := 0 to 883 do begin
      readln(RadioFile,AvgPrt[x]);
      readln(RadioFile,AvgStd[x]);
    end;
    close(RadioFile);
  end
  else begin
    FillChar(Prt,SizeOf(Prt),0);
    FillChar(Strboard,SizeOf(Strboard),0);
    y := 0;
    for x:= 0 to 883 do begin
      Prt[x] := 0;
      Strboard[x] := 0;
      PrtCounter[x] := 0;
      StbdCounter[x] := 0;
    end;
    Totalreturn := 0;
    XCounter := 0;
    while (not EOF(DataFile)) do begin
      {$I-} Read(DataFile,StdRec); {$I+}
      FindFishHeight(Bottomstart);
      if IOResult = 0 then begin
        gotoxy(1,1);
        inc(XCounter);
        if (XCounter mod 10) = 0 then Screen(1,1,LightRed,IntegerToString(XCounter,3) + ' records averaged');
        for x := BottomStart to 883 do begin
          inc(Prt[x],StdRec[32 + 2 * x]);
          inc(PrtCounter[x]);
          inc(Strboard[x],StdRec[33 + 2 * x]);
          inc(StbdCounter[x]);
          inc(Totalreturn,((StdRec[32 + 2 * x] + StdRec[33 + 2 * x]) div 2));
        end;
      end;
    end;
    for x := 0 to 883 do
      if (PrtCounter[x] = 0) or (StbdCounter[x] = 0) then begin
        AvgPrt[x] := 0;
        AvgStd[x] := 0;
      end
      else begin
        AvgPrt[x] := Prt[x]/PrtCounter[x];
        AvgStd[x] := Strboard[x]/StbdCounter[x];
      end;
    assign(RadioFile,Dir + Name + '.cta');
    rewrite(RadioFile);
    for x := 0 to 883 do begin
      writeln(RadioFile,AvgPrt[x]);
      writeln(RadioFile,AvgStd[x]);
    end;
    close(RadioFile);
  end; {else}
  reset(DataFile);
end;

{$I side-gth.pas} {Prof. Guth's SIDESCAN routines}

procedure FilterSpeed;

const
  NumData = 2000;

var
  TempOutfile,CorrOutFile,VTOutFile : text;
  TrueVelArray,TrueHdgArray : array[1..NumData] of shortfloat;
  StartFirst : boolean;
  Lat,Long,Curdepth,xf,yf,h,SumVel,SumHdg : extended;
  Vel : float;
  j,loop,Error,Hrs,Mins,HourTot : integer;
  Time : real;
  TimeStr : string[14];
  HrStr : string[2];
  Tstr : string;

begin
  assign(TempOutFile,PETMARDefaults.VirtualDiskPath + 'TempTrack.txt');
  reset(TempOutFile);
  assign(CorrOutFile,SideScanDefaults.DataPath + 'track.txt');
  rewrite(CorrOutFile);
  assign(VTOutFile,PETMARDefaults.VirtualDiskPath + 'HYDVandT.txt'),
  rewrite(VTOutFile);
  SumVel := 0;
  SumHdg := 0,
  StartFirst := false;
  j := 1;
  while not EOF(TempOutfile) do begin
    if EOLN(TempOutfile) then readln(TempOutfile)
    else begin
      readln(TempOutFile,Lat,Long,TimeStr,Heading,Vel,xf,yf,h);
      TrueVelArray[j] := Vel;
      TrueHdgArray[j] := Heading;
      if j = 5 then StartFirst := true;
      if StartFirst then begin
        for loop := 0 to 4 do begin
          SumVel := SumVel + TrueVelArray[j - loop];
          SumHdg := SumHdg + TrueHdgArray[j - loop];
        end;
        writeln(CorrOutFile,Lat:7:4,Long:9:4,'  ',TimeStr,(SumHdg/5):5:0,(SumVel/5):8:1,xf:12:2,yf:12:2,h:8:5);
        Val(Copy(TimeStr,3,2),Hrs,error);
        Val(Copy(TimeStr,6,2),Mins,error);
        TStr := Copy(TimeStr,9,5);
        StripBlanks(TStr);
        Val(Tstr,Time,error);
        Time := Hrs + Mins / 60 + Time /  3600;
        writeln(VTOutFile,Time:10:6,(SumVel/5):6:1,xf:12:2,yf:12:2,(SumHdg/5):5:0);
        if (j mod 10) = 0 then Screen(1,15,LightRed,IntegerToString(j,3) + ' navigation data points filtered');
        SumVel := 0;
        SumHdg := 0;
      end;
      inc(j);
    end;
  end;
  close(CorrOutFile);
  close(VTOutFile);
  SelectGraphicsMode;
end;


procedure UTMInterpolation;

var
  TempOutFile,OutFile : file of StdRecType;
  x,y : array[0..2650] of shortfloat;
  loop,TempRange : integer;

begin
  assign(COutFile,CFilename);
  reset(COutfile);
  OnRecord := 0;
  BotVal := 25;
  while (not EOF(COutFile)) do begin
    if (OnRecord mod 50) = 0 then Screen(1,1,LightRed,IntegerToString(OnRecord,3) + ' read into array');
    {$I-} Read(COutFile,StdRec);  {$I+}
    if (KeyPressed and (ReadKey = #27)) then break;
    Move(StdRec[19],x[OnRecord],4);
    Move(StdRec[23],y[OnRecord],4);
    inc(OnRecord);
    if OnRecord = 10 then begin
      for i := 16 to 17 do dec(StdRec[i],128);
      TempRange := StdRec[17] * 100 + StdRec[16];
    end;
  end;
  close(COutFile);
  loop := 0;
  case TempRange of
    100 : while loop <= (NumRec - 7) do begin
          if (x[loop]=x[loop+1]) and (x[loop+1]=x[loop+2]) and
          (x[loop+2]=x[loop+3]) and (x[loop+3]=x[loop+4]) and
          (x[loop+4]=x[loop+5]) and (x[loop+5]=x[loop+6]) then begin
            x[loop+1] := x[loop+1] + (x[loop+7] - x[loop+6])/7;
            x[loop+2] := x[loop+2] + 2 * (x[loop+7] - x[loop+6])/7;
            x[loop+3] := x[loop+3] + 3 * (x[loop+7] - x[loop+6])/7;
            x[loop+4] := x[loop+4] + 4 * (x[loop+7] - x[loop+6])/7,
            x[loop+5] := x[loop+5] + 5 * (x[loop+7] - x[loop+6])/7;
            x[loop+6] := x[loop+6] + 6 * (x[loop+7] - x[loop+6])/7;
        y[loop+1] := y[loop+1] + (y[loop+7] - y[loop+6])/7;
        y[loop+2] := y[loop+2] + 2 * (y[loop+7] - y[loop+6])/7;
        y[loop+3] := y[loop+3] + 3 * (y[loop+7] - y[loop+6])/7;
        y[loop+4] := y[loop+4] + 4 * (y[loop+7] - y[loop+6])/7;
        y[loop+5] := y[loop+5] + 5 * (y[loop+7] - y[loop+6])/7;
        y[loop+6] := y[loop+6] + 6 * (y[loop+7] - y[loop+6])/7;
        inc(loop,7);
      end
      else if (x[loop]=x[loop+1]) and (x[loop+1]=x[loop+2]) and
      (x[loop+2]=x[loop+3]) and (x[loop+3]=x[loop+4]) and
      (x[loop+4]=x[loop+5]) then begin
        x[loop+1] := x[loop+1] + (x[loop+6] - x[loop+5])/6;
        x[loop+2] := x[loop+2] + 2 * (x[loop+6] - x[loop+5])/6;
        x[loop+3] := x[loop+3] + 3 * (x[loop+6] - x[loop+5])/6;
        x[loop+4] := x[loop+4] + 4 * (x[loop+6] - x[loop+5])/6;
        x[loop+5] := x[loop+5] + 5 * (x[loop+6] - x[loop+5])/6;
        y[loop+1] := y[loop+1] + (y[loop+6] - y[loop+5])/6;
        y[loop+2] := y[loop+2] + 2 * (y[loop+6] - y[loop+5])/6;
        y[loop+3] := y[loop+3] + 3 * (y[loop+6] - y[loop+5])/6;
        y[loop+4] := y[loop+4] + 4 * (y[loop+6] - y[loop+5])/6;
        y[loop+5] := y[loop+5] + 5 * (y[loop+6] - y[loop+5])/6;
        inc(loop,6);
      end
      else inc(loop);
      if (loop mod 50) = 0 then Screen(1,15,LightRed,IntegerToString(loop,3) + ' interpolated       ');
    end;
  200 : while loop <= (NumRec - 4) do begin
      if (x[loop]=x[loop+1]) and (x[loop+1]=x[loop+2]) and
      (x[loop+2]=x[loop+3]) then begin
        x[loop+1] := x[loop+1] + (x[loop+4] - x[loop+3])/4;
        x[loop+2] := x[loop+2] + 2 * (x[loop+4] - x[loop+3])/4;
        x[loop+3] := x[loop+3] + 3 * (x[loop+4] - x[loop+3])/4;
        y[loop+1] := y[loop+1] + (y[loop+4] - y[loop+3])/4;
        y[loop+2] := y[loop+2] + 2 * (y[loop+4] - y[loop+3])/4;
        y[loop+3] := y[loop+3] + 3 * (y[loop+4] - y[loop+3])/4;
        inc(loop,3);
      end
      else if (x[loop]=x[loop+1]) and (x[loop+1]=x[loop+2]) then begin
        x[loop+1] := x[loop+1] + (x[loop+3] - x[loop+2])/3;
        x[loop+2] := x[loop+2] + 2 * (x[loop+3] - x[loop+2])/3;
        y[loop+1] := y[loop+1] + (y[loop+3] - y[loop+2])/3;
        y[loop+2] := y[loop+2] + 2 * (y[loop+3] - y[loop+2])/3;
        inc(loop,2);
      end
      else inc(loop);
      if (loop mod 50) = 0 then Screen(1,15,LightRed,IntegerToString(loop,3) + ' interpolated       ');
    end;
end; {case}
loop := 0;
reset(COutfile);
while (not EOF(COutFile)) do begin
  if (loop mod 50) = 0 then Screen(1,30,LightRed,IntegerToString(loop,3) + ' records reprocessed       ');
  seek(COutFile,loop);
  {$I-} Read(COutFile,StdRec);  {$I+}
  seek(COutFile,loop);
  Move(x[loop],StdRec[19],4);
  Move(y[loop],StdRec[23],4);
  write(COutfile,StdRec);
```

```
    if (KeyPressed and (ReadKey = #27)) then break;
    inc(loop);
  end;
  close(COutfile);
end;


procedure EditFile;

label
  Bored;

const
  BufferSize = 256;

type
  PosArrayType    = array[1..BufferSize] of PositionType;
  CurPosArrayType = array[1..Buffe [illegible] of HydroSurveyPositionType;

var
  PFile   : file of  HydroSurveyPositionType;
  TempOutFile : file of StdRecType;
  TrackFile : file;
  VTOutFile,TestOutFile,TextOutFile : text;
  PosArray : ^PosArrayType;
  CurPosArray : ^CurPosArrayType;
  CurPos : HydroSurveyPositionType;
  CurHydroPos : HydroSurveyPositionType;
  LastTime,LastXF,LastYF : array[1..2] of float;
  First,DepthBox,RecordLocation,OK,OK2,ShowPoints,ConnectPoints,Done,WayPointFile,ValidReading : boolean;
  EditCh,ch,ch2 : char;
  PointSym : DrawingSymbol;
  MinDepth,MaxDepth,xf1,yf1,xf2,yf2,h,k,Heading1,Heading2,HYDTime1,HYDVel1,HYDTime2,HYDVel2,
  HYDVel,EGGTime,Elev,LastLat,LastLong,Dist,Time,Vel,xf,yf : float;
  EchoTracComPort,XCorner,YCorner,TopDepthLimit,PointColor,XCur,i,Skip,HourOffset,MinuteOffset,
  SecondOffset,BottomStrength,NumRead,Tenths,Tens,LineStyle,LineThick,LineColor,SymSize,Error,SwathWidth,
  SwathColor,x0,y0,x1,y1,TimeInterval,Hr,Min,j : integer;
  NumReadings,NumProc : LongInt;
  FileName,DataPath,HYDDataPath,DataDirectory,DataSubDir,MapDir,WayPointName : PathStr;
  Image : pointer;
  TimeStr : string[14];
  Ext : string3;
  ProjFileName : string;

begin
  HourOffset := 17;
  MinuteOffset := 0;
  SecondOffset := 0;
  NumProc := 0;
  DataPath := SideScanDefaults.DataPath;
  i := 2;
  SelectGraphicsMode;
  ReadIntegerDefaultInGraphicsBox(5,5,'Hours added/subtracted from EGG ', HourOffset);
  ReadIntegerDefaultInGraphicsBox(5,5,'Minutes added/subtracted from EGG ', MinuteOffset);
  ReadIntegerDefaultInGraphicsBox(5,5,'Seconds added/subtracted from EGG ', SecondOffset);
  HYDDataPath := SideScanDefaults.DataPath;
  GetFileFromDirectory('Hydrographic track','*.HYD',HYDDataPath,FName);
  assign(PFile,FName);
```

```
 reset(PFile);
 CFileName := SideScanDefaults.DataPath;
 GetFileNameDefExt(1,1,'edited record','EGG',CFileName);
 assign(TempOutFile,PETMARDefaults.VirtualDiskPath + 'TempOutFile.EGG');
 rewrite(TempOutFile);
 reset(DataFile);
 while not EOF(DataFile) do begin
   read(DataFile,StdRec);
   inc(NumProc);
   if (NumProc mod 10) = 0 then Screen(1,1,LightRed,IntegerToString(NumProc,3) + ' records with times changed');
   for i := 1 to 3 do dec(StdRec[i],128);
   StdRec[3] := StdRec[3] + HourOffset;
   StdRec[2] := StdRec[2] + MinuteOffset;
   StdRec[1] := StdRec[1] + SecondOffset;
   while (StdRec[1]) >= 60 do begin
     StdRec[2] := StdRec[2] + 1;
     StdRec[1] := StdRec[1] - 60;
   end;
   while (StdRec[2]) >= 60 do begin
     StdRec[3] := StdRec[3] + 1;
     StdRec[2] := StdRec[2] - 60;
   end;
   for i := 1 to 3 do inc(StdRec[i],128);
   write(TempOutfile,StdRec);
 end;
 close(TempOutFile);
 DepthLimit := 45;
 DataSubDir := SideScanDefaults.DataPath;
 MapDir := '';
 UTMInitialize;
{$IfDef WriteOutPut}
 assign(TextOutFile,PETMARDefaults.VirtualDiskPath + 'TempTrack.txt');
 rewrite(TextOutFile);
{$EndIf}
 PETOver.AllowChangesInFileFromDirectory := true;
 MinDepth := 9999;
 MaxDepth := -9999;
 First := true;
 i := 1;
 j := 0;
 while not EOF(PFile) do begin
   read(PFile,CurPos);
   with CurPos.Position do if abs(Lat) > 0.00001 then begin
     Val(Copy(TimeStr,1,2),Hr,error);
     Val(Copy(TimeStr,4,2),Min,error);
     TStr := Copy(TimeStr,7,5);
     StripBlanks(TStr);
     Val(Tstr,Time,error);
     Time := Hr + Min / 60 + Time /  3600;
     ValidReading := true;
     RawProject(1.0*Lat,1.0*Long,xf,yf);
     GetMapScaleFactor(Lat/DegToRad,Long/DegToRad,h,k);
     if First then First := false
     else begin
       Dist := sqrt(sqr((xf-LastXF[1])/h) + sqr((yf-LastYF[1])/k));
       if (Dist > 0.001) and (abs(Lat) > 0.001) and
       (Dist < 25) then begin
         HeadingOfLine((xf-LastXF[1])/h,(yf-LastYF[1])/k,Heading);
```

```
        Vel := (0.62/1.15*0.001 * Dist) / (Time - LastTime[1]);
        writeln(TextOutFile,Lat/DegToRad:9:6,Long/DegToRad:12:6,' ',TimeStr,RealToString(Heading,5,0)+
          RealToString(Vel,8,1),xf:12:2,yf:12:2,h:8:5);
        if (j mod 10) = 0 then Screen(1,1,LightRed,IntegerToString(j,3) + ' navigation data points read');
        inc(j);
      end;
    end;
    Lastxf[1] := xf;
    Lastyf[1] := yf;
    LastTime[1] := Time;
  end;
  inc(i);
end;
Bored:;
i := 2;
FName := '';
close(TextOutFile);
FilterSpeed;
assign(COutFile,CFileName);
rewrite(COutFile);
assign(TempOutfile,PETMARDefaults.VirtualDiskPath + 'TempOutFile.EGG');
reset(TempOutFile);
assign(VTOutFile,PETMARDefaults.VirtualDiskPath + 'HYDVandT.txt');
reset(VTOutFile);
NumProc := 0;
assign(JunkFile,PETMARDefaults.VirtualDiskPath + 'Junk.txt');
rewrite(JunkFile);
while not EOF(TempOutFile) do begin
  read(TempOutFile,StdRec);
  inc(NumProc);
  if (NumProc mod 10) = 0 then Screen(1,1,LightRed,IntegerToString(NumProc,3) +
    ' records rewritten with nav data');
  for i := 11 to 12 do dec(StdRec[i],128);
  for i := 1 to 3 do dec(StdRec[i],128);
  if NumProc = 1 then begin
    readln(VTOutFile,HYDTime1,HYDVel1,xf1,yf1,Heading1);
    readln(VTOutFile,HYDTime2,HYDVel2,xf2,yf2,Heading2);
  end;
  EGGTime := StdRec[3] + StdRec[2]/60 + StdRec[1]/3600; {hours}
  while ((EGGTime < HYDTime1) or (EGGTime > HYDTime2)) and
  (not EOF(VTOutFile)) do begin
    HYDTime1 := HYDTime2;
    HYDVel1 := HYDVel2;
    xf1 := xf2;
    yf1 := yf2;
    Heading1 := Heading2;
    readln(VTOutFile,HYDTime2,HYDVel2,xf2,yf2,Heading2);
  end;
  xf := xf1 + ((EGGTime - HYDTime1)/(HYDTime2 - HYDTime1)) * (xf2 - xf1);
  yf := yf1 + ((EGGTime - HYDTime1)/(HYDTime2 - HYDTime1)) * (yf2 - yf1);
  HYDVel := HYDVel1 + ((EGGTime - HYDTime1)/(HYDTime2 - HYDTime1)) * (HYDVel2 - HYDVel1);
  if HYDVel >= 10.0 then begin
    Tenths := round(HYDVel * 10 - 100);
    Tens := 1;
  end
  else begin
    Tenths := round(HYDVel * 10);
    Tens := 0;
    end;
    xutm := xf;
    yutm := yf;
    Move(xutm,StdRec[19],4);
    Move(yutm,StdRec[23],4);
    writeln(JunkFile,' HTs: ',HYDTime1:8:6,HYDTime2:11:6,' ET: ',EGGTime:8:6,
      ' xf: ',xf:12:2,' yf: ',yf:12:2,' Vel: ',HYDVel:4:1);
    StdRec[11] := Tenths;
    StdRec[12] := Tens;
    for i := 1 to 3 do inc(StdRec[i],128);
    for i := 11 to 12 do inc(StdRec[i],128);
    for i := 13 to 14 do dec(StdRec[i],128);
    StdRec[14] := round(Heading2) div 100;
    StdRec[13] := round(Heading2) - (StdRec[14] * 100);
    for i := 13 to 14 do inc(StdRec[i],128);
    write(COutFile,StdRec);
  end;
  close(COutFile);
  close(VTOutFile);
  close(TempOutFile);
  close(JunkFile);
  SelectGraphicsMode;
  UTMInterpolation;
end;

{$I side-msc.pas} {Midn Linder's error checking routines and the demonstration slide show procedure}

procedure DrawBox;

const
  MosaicSize = 1800;

begin
  SetColor(LightRed);
  MapProj.AdjustCoord(ZeroXOffset,ZeroYOffset,TempMapX,TempMapY);
  MoveTo(TempMapX,TempMapY);
  MapProj.AdjustCoord(ZeroXOffset,(ZeroYOffset-MosaicSize),Temp2MapX,Temp2MapY);
  LineTo(Temp2MapX,Temp2MapY);
  MapProj.AdjustCoord(ZeroXOffset,(ZeroYOffset-MosaicSize),Temp2MapX,Temp2MapY);
  LineTo(Temp2MapX,Temp2MapY);
  MapProj.AdjustCoord((ZeroXOffset+MosaicSize),(ZeroYOffset-MosaicSize),TempMapX,TempMapY);
  LineTo(TempMapX,TempMapY);
  MapProj.AdjustCoord((ZeroXOffset+MosaicSize),ZeroYOffset,Temp2MapX,Temp2MapY);
  LineTo(Temp2MapX,Temp2MapY);
  MapProj.AdjustCoord(ZeroXOffset,ZeroYOffset,TempMapX,TempMapY);
  LineTo(TempMapX,TempMapY);
end;


procedure Mosaic;

const
  BeginVal = 0;
  MosaicSize = 1800;

type
  MosaicRowType = array[0..MosaicSize] of byte;
  RegisteredImageType = record
```

```
    xcp,ycp   : array[1..4] of integer;
    ImgName : PathStr;
  end;

var
  MosaicRow : ^MosaicRowType;
  NewMosaicFile,MosaicFile : file of MosaicRowType;
  ImageRows : array[0..MosaicSize] of ^MosaicRowType;
  CheckFile,XYFile,OldXYFile,IndexFile : text;
  Dir,Dir2 : DirStr;
  Name,Name2 : NameStr;
  Ext,Ext2 : ExtStr;
  Done : boolean;
  PortStbd,MosCh,ChnlCh : char;
  xgrid,ygrid,Min,Dist,MinDist,z,Temphead : float;
  X0,Y0,xtemp,Closest,HdgDesired,Poss1BigHdg,Poss2BigHdg,StartVal,BothLoop,LoopMax,BottomStart,
  i,j : integer;
  ImageXFinal,ImageYFinal,Xcheck,Ycheck : longint;
  ProjFileName,MapDir,FileName : pathstr;
  FileInfo : SearchRec;
  Dataline : string;

begin
  ZeroXOffset := 376800;
  ZeroYOffset := 4312000;
  repeat
    i := 1;
    MenuStr := '^Options\~Make single mosaic\~Combine existing mosaics\~Xit';
    MenuHelpFileName := 'ss-mosai.hlp';
    MakeMenu(MenuStr,5,5,MosCh,i);
    case MosCh of
      'M': begin
           ReadLongIntegerDefaultInGraphicsBox(5,5,'X utm value of upper left corner ',ZeroXOffset);
           ReadLongIntegerDefaultInGraphicsBox(5,5,'Y utm value of upper left corner ',ZeroYOffset);
           Filename := SideScanDefaults.Datapath;
           GetFileNameDefExt(1,1,'Mosaic file','bn1',FileName);
           FSplit(FileName,Dir,Name,ext);
           new(MosaicRow);
           assign(MosaicFile,Filename);
           FillChar(MosaicRow^, sizeof(MosaicRow^),0);
           UTMInitialize;
           DrawBox;
           HdgDesired := 0;
           for y := 0 to MosaicSize do begin
             if ((y mod 50) = 0) then Screen(30,-1,LightRed,IntegerToString(y,4) + ' ' + MemAvailString);
             GetMem(ImageRows[y],succ(MosaicSize));
             ImageRows[y]^ := MosaicRow^;
           end {for y};
           repeat
             repeat
               i := 3;
               MenuStr := '^Channel displayed\~Port\~Starboard\~Both';
               MakeMenu(MenuStr,5,5,ChnlCh,i);
             until ChnlCh in ['P','S','B'];
             LoopMax := 1;
             case ChnlCh of
               'P': StartVal := 32;
               'S': StartVal := 33;
  'B': LoopMax := 2;
end;
NewImage;
RadiometricCorrect;
OnRecord := 0;
for BothLoop := 1 to LoopMax do begin
  if BothLoop = 2 then reset(DataFile);
  while (not EOF(DataFile)) do begin
    inc(OnRecord);
    if (OnRecord mod 10) = 0 then Screen(1,1,LightRed,IntegerToString(OnRecord,3) +
      ' complete        ');
    {$I-} Read(DataFile,StdRec); {$I+}
    if (KeyPressed and (ReadKey = #27)) then break;
    if IOResult = 0 then begin
      AnalyzeRecord;
      FindFishHeight(BottomStart);
      while BottomStart <= 883 do begin
        SlantDist := 1.0 * BottomStart * TransmitPeriod / 883 * 1500 * 0.001 * 0.5;
        if sqr(SlantDist) >= sqr(FishHeight) then
          DistFromCent := sqrt(sqr(SlantDist) - sqr(FishHeight))
        else DistFromCent := 0;
        case ChnlCh of
          'P':begin
               Finalxutm := xutm-DistFromCent*CosDeg(Heading);
               Finalyutm := yutm+DistFromCent*SinDeg(Heading);
             end;
          'S':begin
               Finalxutm := xutm+DistFromCent*CosDeg(Heading);
               Finalyutm := yutm-DistFromCent*SinDeg(Heading);
             end;
          'B':case BothLoop of
               1:begin
                  StartVal := 33;
                  Finalxutm:= xutm+DistFromCent*CosDeg(Heading);
                  Finalyutm:= yutm-DistFromCent*SinDeg(Heading);
                end;
               2:begin
                  StartVal := 32;
                  Finalxutm:= xutm-DistFromCent*CosDeg(Heading);
                  Finalyutm:= yutm+DistFromCent*SinDeg(Heading);
                end;
             end;
        end;
        Finalxutm := Finalxutm - 25*SinDeg(Heading);
        Finalyutm := Finalyutm - 25*CosDeg(Heading);
        ImageXFinal := round(Finalxutm - ZeroXOffset);
        ImageYFinal := round(ZeroYOffset - Finalyutm);
        if (ImageXFinal >= 0) and (ImageXFinal <= MosaicSize) and
          (ImageYFinal >= 0) and (ImageYFinal <= MosaicSize) then begin
          xtemp := StartVal + 2 * BottomStart;
          if (AvgStd[BottomStart] > 0) then
            StdRec[xtemp] := round(StdRec[xtemp] * 32 / AvgStd[BottomStart]);
          if StdRec[xtemp] <= 64 then begin
            if ((OnRecord mod 5) = 0) and ((BottomStart mod 50) = 0) then begin
              AdjustCoord(Finalxutm,Finalyutm,X0,Y0);
              putpixel(X0,Y0,red);
            end;
            ImageRows[ImageYFinal]^[ImageXFinal] := StdRec[xtemp];
```

```
                end;
              end;
              inc(BottomStart,4);
            end;
          end;
        end;
        close(Datafile);
        FileOpen := false;
        OnRecord := 0;
      end; {for}
    until AnswerIsYesXY(1,5,'Done');
    rewrite(MosaicFile);
    for i := 0 to MosaicSize do beg
      write(MosaicFile,ImageRows[i
      if ((i mod 50) = 0) then Screen(30,-1,LightRed,IntegerToString(i,4) + '  rows written to file');
    end;
    close(MosaicFile);
    assign(XYFile,Dir + Name + '.XY');
    rewrite(XYFile);
    writeln(XYFile,BeginVal:10,BeginVal:10,ZeroXOffset:10,ZeroYOffset:10);
    writeln(XYFile,MosaicSize:10,BeginVal:10,(ZeroXOffset + MosaicSize):10,ZeroYOffset:10);
    writeln(XYFile,MosaicSize:10,MosaicSize:10,(ZeroXOffset + MosaicSize):10,
      (ZeroYOffset - MosaicSize):10);
    writeln(XYFile,BeginVal:10,MosnicSize:10,ZeroXOffset:10,(ZeroYOffset - MosaicSize):10);
    close(XYFile);
  end;
'C': begin
    Filename := SideScanDefaults.Datapath;
    GetFileNameDefExt(1,1,'Combined mosaic file','bn1',FileName);
    FSplit(FileName,Dir,Name,ext);
    new(MosaicRow);
    assign(NewMosaicFile,Filename);
    FillChar(MosaicRow^, sizeof(MosaicRow^),0);
    for y := 0 to MosaicSize do begin
      if ((y mod 50) = 0) then Screen(30,-1,LightRed,IntegerToString(y,4) + ' ' + MemAvailString);
      GetMem(ImageRows[y],succ(MosaicSize));
      ImageRows[y]^ := MosaicRow^;
    end {for y};
    repeat
      DataSubDir := SideScanDefa    Datapath;
      GetFileFromDirectory('Existing mosaic','*.BN1',DataSubDir,FName);
      if FName = '' then halt;
      FSplit(FName,Dir2,Name2,ext2);
      assign(MosaicFile,FName);
      reset(MosaicFile);
      for i := 0 to MosaicSize do begin
        read(MosaicFile,mosaicRow^);
        for j := 0 to MosaicSize do
          if mosaicrow^[j] > 0 then ImageRows[i]^[j] := mosaicrow^[j];
        if ((i mod 50) = 0) then Screen(30,-1,LightRed,
          IntegerToString(i,4) + '  rows read from file');
      end;
      close(MosaicFile);
    until AnswerIsYesXY(1,5,'Done
    rewrite(NewMosaicFile);
    for i := 0 to MosaicSize do begin
      write(NewMosaicFile,ImageRows[i]^);
      if ((i mod 50) = 0) then Screen(30,-1,LightRed,
              IntegerToString(i,4) + '  rows written to file');
          end;
          close(NewMosaicFile);
          assign(XYFile,Dir + Name + '.XY');
          rewrite(XYFile);
          assign(OldXYFile,Dir2 + Name2 + '.XY');
          reset(OldXYFile);
          for i := 1 to 4 do begin
            readln(OldXYFile,Dataline);
            writeln(XYFile,Dataline);
          end;
          close(XYFile);
          close(OldXYFile);
        end;
    end;
  until MosCh in ['M','C','X'];
  if MosCh in ['C','M'] then begin
    assign(IndexFile,Dir + Name + '.idx');
    rewrite(IndexFile);
    writeln(IndexFile,'EGG side scan sonar');
    writeln(IndexFile,'   1',succ(MosaicSize):8,'    1',succ(MosaicSize):8);
    writeln(IndexFile,'1');
    writeln(IndexFile,'SONAR');
    writeln(IndexFile,Filename);
    close(IndexFile);
  end;
  if MosCh <> 'X' then
    for y := 0 to MosaicSize do begin
      if ((y mod 50) = 0) then Screen(30,-1,LightRed,IntegerToString(y,4) + ' ' + MemAvailString);
      FreeMem(ImageRows[y],succ(MosaicSize));
    end {for y};
end;


procedure VerifySideScanDefaults;

begin
  SideScanDefaults.DataPath := '';
  if FileIsPresent('SideScan.DEF') then
    begin
      assign(DefaultsFile,'SideScan.DEF');
      reset(DefaultsFile);
      read(DefaultsFile,SideScanDefaults);
      close(DefaultsFile);
    end
  else
    begin
      GetDOSPath('side scan data',SideScanDefaults.DataPath);
      assign(DefaultsFile,'SideScan.DEF');
      rewrite(DefaultsFile);
      write(DefaultsFile,SideScanDefaults);
      close(DefaultsFile);
    end;
end;


procedure SlantRngCorrect;
```

```
var
  i : integer;

begin
  for i := 0 to RecXMax do begin
    TrueDist := (NumRecs * OneOrBoth) * i * Range / ScreenXMax;
    SlantDist := sqrt(sqr(TrueDist) + sqr(FishHeight));
    SlantTime := 2 * SlantDist / 1.5;
    LUTInc := 2 * round(SlantTime/TransmitPeriod * 883);
    if Invert then begin
      StartPort := 33;
      StartStar := 32;
    end
    else begin
      StartPort := 32;
      StartStar := 33;
    end;
    case PortCh of
      'P': ScreenLUT[RecXMax-i] := StartPort + LUTInc;
      'S': ScreenLUT[i] := StartStar + LUTInc;
      'B': begin
            ScreenLUT[RecXMax - i] := StartPort + LUTInc;
            ScreenLUT[succ(RecXMax) + i] := StartStar + LUTInc;
          end;
    end;
  end;
end;


procedure AspectRatioCorrect;

var
  x : integer;

begin
  counter := 0;
  SpeedInterval := (Speed * 0.508 * 0.001 * TransmitPeriod);
  PixelDist := ((NumRecs * OneOrBoth) * Range / ScreenXMax);
  NumPixelsShow := round(SpeedInterval/PixelDist),
  Remainder := SpeedInterval/PixelDist - NumPixelsShow;
  SumRemainder := SumRemainder + Remainder;
  repeat
    if (NumPixelsShow >= 1.00) or (not(RepeatRow)) then begin
      writeln(JunkFile,(y + ScreensDone * ScreenYMax));
      writeln(JunkFile,OnRecord);
      for x := 0 to (ScreenXMax div NumRecs) do
        PutPixel((x + XDeflection),y,ColorBytes[StdRec[ScreenLUT[x]]]);
      if CopyImage then begin
        for x := ScreenXMax downto 0 do
          OutVal[ScreenXMax-x] := StdRec[ScreenLUT[x]];
        BlockWrite(ImageFil      tVal,1);
        inc(RowCounter);
      end,
    end;
    if SumRemainder <= -1 then SumRemainder := SumRemainder + 1.00
    else if (NumPixelsShow >= 1.00) or (not(RepeatRow)) then
      if Invert then inc(y)
      else dec(y):
```

```
    inc(Counter);
    if ((y = 10) and not Invert) or ((y >= ScreenYMax) and Invert) then begin
      inc(ScreensDone);
      Counter := NumPixelsShow;
      if (ColsSidebySide > 1) then begin
        inc(ColsDone);
        if ColsDone = ColsSidebySide then begin
          PressKeyContinues;
          SelectGraphicsMode:
          ColsDone := 0;
        end;
      end
      else if WaitAtBottom then begin
        PETMARImageOption(true,DefaultPrint);
        SelectGraphicsMode;
      end:
      if Invert then y := 0 else y := ScreenYMax;
    end;
    if SumRemainder >= 1 then begin
      SumRemainder := SumRemainder - 1.00;
      inc(NumPixelsShow);
    end;
  until (counter = NumPixelsShow) or (NumPixelsShow < 1);
end;


procedure GetPosition;

var
  x0,y0,x1,y1,OldY,OldRec,DistLoop,Points : integer;

begin
  close(JunkFile);
  if Projection.Pname <> UTMEllipsoidal then
    MessageToContinueXY(1,1,'Not UTM projection: problems likely.');
  xw := ScreenXMax div 2;
  yw := ScreenYMax div 2;
  Points := 1;
  if ch='M' then Points := 2;
  for DistLoop := 1 to Points do begin
    GetXYLocation(xw,yw,0,0,ScreenXMax,ScreenYMax,Done,true,true,DummyDisplayCursorLocation);
    case DistLoop of
      1: begin
          x0 := xw;
          y0 := yw;
        end;
      2: begin
          x1 := xw;
          y1 := yw;
        end;
    end;
    XDesired := xw;
    case PortCh of
      'B' : DistFromCent := abs(RecXMax - XDesired) * Range / RecXMax;
      'S' : DistFromCent := XDesired * Range / RecXMax;
      'P' : DistFromCent := (ScreenXMax - XDesired) * Range / RecXMax;
    end;
    YDesired := yw + ScreensDone * ScreenYMax;
  assign(JunkFile,PETMARDefaults.VirtualDiskPath + 'YandRec.txt');
  reset(JunkFile);
  repeat
    readln(JunkFile,OldY);
    readln(JunkFile,OldRec);
  until (OldY = YDesired) or EOF(JunkFile);
  close(JunkFile);
  if OldRec < NumRec then seek(DataFile,OldRec)
  else seek(DataFile,pred(NumRec));
  read(DataFile,StdRec);
  for i := 0 to 17 do dec(StdRec[i],128);
  Heading := StdRec[14] * 100 + StdRec[13];
  Move(StdRec[19],Centxutm,4);
  Move(StdRec[23],Centyutm,4);
  if DistLoop = 1 then begin
    if ((xw < RecXMax) and (PortCh = 'B') and (not Invert)) or (PortCh = 'P') or
      ((xw > RecXMax) and Invert and (PortCh = 'B')) then begin
      Finalxutm := Centxutm-DistFromCent*CosDeg(Heading);
      Finalyutm := Centyutm+DistFromCent*SinDeg(Heading);
    end
    else begin
      Finalxutm := Centxutm+DistFromCent*CosDeg(Heading);
      Finalyutm := Centyutm-DistFromCent*SinDeg(Heading);
    end;
    Finalxutm := Finalxutm - 25*SinDeg(Heading);
    Finalyutm := Finalyutm - 25*CosDeg(Heading);
    InverseProject(finalxutm,finalyutm,Lat,Long);
    MessagetoContinueXY(1,15,'xutm: ' + RealToString(Finalxutm,8,2) + 'm' +
      ' yutm: ' + RealToString(Finalyutm,8,2) + 'm\' +
      LatLongToString(lat/degtorad,long/degtorad,decminutes) + '\');
   end
   else begin
    if ((xw < RecXMax) and (PortCh = 'B') and (not Invert)) or (PortCh = 'P') or
      ((xw > RecXMax) and Invert and (PortCh='B')) then begin
      Final2xutm := Centxutm-DistFromCent*CosDeg(Heading);
      Final2yutm := Centyutm+DistFromCent*SinDeg(Heading);
    end
    else begin
      Final2xutm := Centxutm+DistFromCent*CosDeg(Heading);
      Final2yutm := Centyutm-DistFromCent*SinDeg(Heading);
    end;
    Final2xutm := Final2xutm - 25*SinDeg(Heading);
    Final2yutm := Final2yutm - 25*CosDeg(Heading);
    setcolor(red);
    line(x0,y0,x1,y1);
    InverseProject(final2xutm,final2yutm,Lat,Long);
    MessagetoContinueXY(1,15,'xutm: ' + RealToString(Final2xutm,8,2) + 'm' +
      ' yutm: ' + RealToString(Final2yutm,8,2) + 'm\' +
      LatLongToString(lat/degtorad,long/degtorad,decminutes) + '\');
    PointDist := sqrt(sqr(Finalxutm-Final2xutm) + sqr(Finalyutm-Final2yutm));
    MessageToContinueXY(1,15,'Distance = ' + RealToString(PointDist,8,2) + 'm\');
   end;
  end;
  append(JunkFile);
  seek(DataFile,OnRecord);
end;
```

```
procedure MakeIDXandXYFiles;

var
  Dir : Dirstr;
  Name : Namestr;
  Ext : Extstr;
  i : integer;

begin
  FSplit(FName,Dir,Name,ext);
  assign(IndexFile,Dir + Name + '.idx');
  rewrite(IndexFile);
  writeln(IndexFile,'EGG side scan sonar');
  writeln(IndexFile,'    1',succ(ScreenXMax):8,'    1',RowCounter:8);
  writeln(IndexFile,'1');
  writeln(IndexFile,'SONAR');
  writeln(IndexFile,Name + '.BN1');
  assign(XYFile,Dir + Name + '.XY');
  rewrite(XYFile);
  BeginVal := 0;
  if Projection.Pname <> UTMEllipsoidal then
    MessageToContinueXY(1,1,'Not UTM projection: problems likely.');
  {Image 0,0}
  XDesired := ScreenXMax;
  xw := ScreenXMax;
  case PortCh of
    'B' : DistFromCent := abs(RecXMax - XDesired) * Range / RecXMax;
    'S' : DistFromCent := XDesired * Range / RecXMax;
    'P' : DistFromCent := (ScreenXMax - XDesired) * Range / RecXMax;
  end;
  reset(DataFile);
  read(DataFile,StdRec);
  for i := 0 to 17 do dec(StdRec[i],128);
  Heading := StdRec[14] * 100 + StdRec[13];
  Move(StdRec[19],Centxutm,4);
  Move(StdRec[23],Centyutm,4);
  if ((xw < RecXMax) and (PortCh = 'B') and (not Invert)) or (PortCh = 'P') or
    ((xw > RecXMax) and Invert and (PortCh = 'B')) then begin
    Finalxutm := Centxutm-DistFromCent*CosDeg(Heading);
    Finalyutm := Centyutm+DistFromCent*SinDeg(Heading);
  end
  else begin
    Finalxutm := Centxutm+DistFromCent*CosDeg(Heading);
    Finalyutm := Centyutm-DistFromCent*SinDeg(Heading);
  end;
  Finalxutm := Finalxutm - 25*SinDeg(Heading);
  Finalyutm := Finalyutm - 25*CosDeg(Heading);
  writeln(XYFile,BeginVal:10,BeginVal:10,Finalxutm:10:0,Finalyutm:10:0);
  {Image SXM,0}
  XDesired := 0;
  xw := 0;
  case PortCh of
    'B' : DistFromCent := abs(RecXMax - XDesired) * Range / RecXMax;
    'S' : DistFromCent := XDesired * Range / RecXMax;
    'P' : DistFromCent := (ScreenXMax - XDesired) * Range / RecXMax;
  end;
  if ((xw < RecXMax) and (PortCh = 'B') and (not Invert)) or (PortCh = 'P') or
    ((xw > RecXMax) and Invert and (PortCh = 'B')) then begin
  Finalxutm := Centxutm-DistFromCent*CosDeg(Heading);
  Finalyutm := Centyutm+DistFromCent*SinDeg(Heading);
end
else begin
  Finalxutm := Centxutm+DistFromCent*CosDeg(Heading);
  Finalyutm := Centyutm-DistFromCent*SinDeg(Heading);
end;
Finalxutm := Finalxutm - 25*SinDeg(Heading);
Finalyutm := Finalyutm - 25*CosDeg(Heading);
writeln(XYFile,ScreenXMax.10,BeginVal:10,Finalxutm:10:0,Finalyutm:10:0);
{Image SXM,SYM}
XDesired := 0;
xw := 0;
case PortCh of
  'B' : DistFromCent := abs(RecXMax - XDesired) * Range / RecXMax;
  'S' : DistFromCent := XDesired * Range / RecXMax;
  'P' : DistFromCent := (ScreenXMax - XDesired) * Range / RecXMax;
end;
seek(DataFile,pred(NumRec));
read(DataFile,StdRec);
for i := 0 to 17 do dec(StdRec[i],128);
Heading := StdRec[14] * 100 + StdRec[13];
Move(StdRec[19],Centxutm,4);
Move(StdRec[23],Centyutm,4);
if ((xw < RecXMax) and (PortCh = 'B') and (not Invert)) or (PortCh = 'P') or
  ((xw > RecXMax) and Invert and (PortCh = 'B')) then begin
  Finalxutm := Centxutm-DistFromCent*CosDeg(Heading);
  Finalyutm := Centyutm+DistFromCent*SinDeg(Heading);
end
else begin
  Finalxutm := Centxutm+DistFromCent*CosDeg(Heading);
  Finalyutm := Centyutm-DistFromCent*SinDeg(Heading);
end;
Finalxutm := Finalxutm - 25*SinDeg(Heading);
Finalyutm := Finalyutm - 25*CosDeg(Heading);
writeln(XYFile,ScreenXMax:10,(y + ScreensDone * ScreenYMax):10,Finalxutm:10:0,Finalyutm:10:0);
{Image 0,SYM}
XDesired := ScreenXMax;
xw := ScreenXMax;
case PortCh of
  'B' : DistFromCent := abs(RecXMax - XDesired) * Range / RecXMax;
  'S' : DistFromCent := XDesired * Range / RecXMax;
  'P' : DistFromCent := (ScreenXMax - XDesired) * Range / RecXMax;
end;
if ((xw < RecXMax) and (PortCh = 'B') and (not Invert)) or (PortCh = 'P') or
  ((xw > RecXMax) and Invert and (PortCh = 'B')) then begin
  Finalxutm := Centxutm-DistFromCent*CosDeg(Heading);
  Finalyutm := Centyutm+DistFromCent*SinDeg(Heading);
end
else begin
  Finalxutm := Centxutm+DistFromCent*CosDeg(Heading);
  Finalyutm := Centyutm-DistFromCent*SinDeg(Heading);
end;
Finalxutm := Finalxutm - 25*SinDeg(Heading);
Finalyutm := Finalyutm - 25*CosDeg(Heading);
writeln(XYFile,BeginVal:10,(y + ScreensDone * ScreenYMax):10,Finalxutm:10:0,Finalyutm:10:0);
close(XYFile);
close(ImageFile);
```

```
  close(IndexFile);
end,


procedure SideScanOps;

label
  Bored;

var
  TFile : text;
  BadPick,RadioData,MosaicIndicator,RadioCorrect,SkipCalcs,ShowBar,BigRec : boolean;
  RecalcParameter,OldFishHeight,LastRange : float;
  i,MemPosition,MosaicLoop,SaveRecNum,BottomStart : integer;
  MapDir,ProjFileName,ImageFileName,DataSubDir : PathStr;
  xl,yl : word;

begin
  VerifySideScanDefaults;
  GraphInit;
  UTMInitialize;
  FileOpen := false;
  OldFishHeight := 0;
  RecalcParameter := 0.05;
  NumRecs := 1;
  ColsSidebySide := 0;
  ColSkip := 1;
  xl := 100;
  yl := 100;
  BottomChannel := 'B';
  repeat
    repeat
      ColsSidebySide := 1;
      BotVal := 25;
      CopyImage := false;
      SkipCalcs := false;
      Invert := false;
      RadioCorrect := false;
      RadioData := false;
      ShowBar := true;
      WaitAtBottom := true;
      with PETMARDefaults do
        if SuperVGAMode > 10 then NewGraphicsMode(SuperVGAMode,SuperVGAMode)
        else SelectGraphicsMode;
      ch := ' ';
      i := 1;
      MenuStr := '^Display\~One sonograph\~Multiple sonographs\~Altitude distribution\~Digital mosaic' +
        '\~Frequency distribution\~Profile across track\~Q:Demo';
      MenuStr := MenuStr + '\^Options\~Create EGG subset\~Ground register\~Hydrographic options' +
        '\~Image processing options\~Sediment analysis\~Xit';
      MenuHelpFileName := 'ss-main.hlp';
      MakeMenu(MenuStr,0,0,ch,i);
      if ch in ['A','C','F','G','P'] then NewImage;
      case ch of
        'Q' : Demonstration;
        'A' : FishHeightPlot;
        'D' : begin
            NewGraphicsMode(PETMARDefaults.DefGraphDriver,DefGraphMode);
```

```
                Mosaic;
              end;
          'G' : EditFile;
          'F' : AcrossTrackFrequencies;
          'M' : begin
                NumRecs := 2;
                ReadLongIntegerDefaultInGraphicsBox(5,5,'Number of records to show (3 max)',NumRecs);
                MosaicIndicator := true;
                SelectGraphicsMode;
              end;
          'H' : begin
                DepthLimit := 45;
                DataSubDir := SideScanDefaults.DataPath;
                MapDir := SideScanDefaults.DataPath;
                NewGraphicsMode(PETMARDefaults.DefGraphDriver,DefGraphMode);
                UTMInitialize;
                HydrographicSurvey(true,LightRed,DepthLimit,
                   MapProj.ProjectSymbol,false,Box,DataSubDir,'')
              end;
          'I' : begin
                NewGraphicsMode(PETMARDefaults.DefGraphDriver,DefGraphMode);
                SatelliteImage(true);
                UTMInitialize;
              end;
          'P' : DoProfile;
          'C' : Subset;
          'S' : begin
                NewGraphicsMode(PETMARDefaults.DefGraphDriver,DefGraphMode);
                SievePlotting;
              end;
        end;
      until ch in ['O','M','X'];
      if ch in ['O','M'] then begin
        if ch = 'O' then NewImage;
        repeat
          if ch = 'O' then begin
            NumRecs := 1;
            MosaicIndicator := false;
          end;
          GraphInit;
          MosaicLoop := 1;
          while MosaicLoop <= NumRecs do begin
            if MosaicIndicator then begin
              NewImage;
              WaitAtBottom := false;
            end;
            repeat
              i := 3;
              MenuStr := '^Channel displayed\~Port\~Starboard\~Both\^Display preferences' +
                '\~Express\~Customized\~Abort';
              MenuHelpFileName := 'ss-sono.hlp';
              MakeMenu(MenuStr,5,5,PortCh,i);
              case PortCh of
                'E': begin
                       ColsSidebySide := 1;
                       BotVal := 25;
                       CopyImage := false;
                       SkipCalcs := false;
        Invert := false;
        RadioCorrect := false;
        RadioData := false;
        ShowBar := false;
        WaitAtBottom := false;
      end;
    'C': begin
        repeat
          i := 99;
          MenuStr := '^Modify preferences' +
          '\~Bottom tracking, ' + ChannelName(BottomChannel) +
          '\~Copy to image file, ' + YesOrNo(CopyImage) +
          '\~Display status bar, ' + YesOrNo(ShowBar) +
          '\~Edit bottomvalue, ' + IntegerToString(BotVal,3) +
          '\~Invert, ' +  YesOrNo(Invert) +
          '\~Number of columns to display, ' + IntegerToString(ColsSidebySide,3) +
          '\~Radiometric corrections, ' + YesOrNo(RadioCorrect) +
          '\~Target color, ';
          if NormalColor then MenuStr := MenuStr + 'White'
          else MenuStr := MenuStr + 'Black';
          MenuStr := MenuStr + '\~Wait when screen full, ' +
            YesOrNo(WaitAtBottom) + '\~Xit';
          MenuHelpFileName := 'ss-pref.hlp';
          MakeMenu(MenuStr,5,5,DispCh,i);
          case DispCh of
            'B': begin
                  i := 1;
                  MakeMenu('^Bottom tracking channel\~Port\~Starboard\~Both',
                    5,5,BottomChannel,i);
                end;
            'C': CopyImage := not CopyImage;
            'D': ShowBar := not ShowBar;
            'E': ReadIntegerDefaultInGraphicsBox(-5,-5,'New bottom value',BotVal);
            'I': Invert := not Invert;
            'N': if not MosaicIndicator then begin
                  ReadIntegerDefaultInGraphicsBox(1,1,'Display n columns (3 max)',
                    ColsSidebySide);
                  NumRecs := NumRecs + ColsSidebySide - 1;
                end;
            'W': WaitAtBottom := not WaitAtBottom;
            'R': RadioCorrect := not RadioCorrect;
            'T': begin
                  for i := 0 to 255 do
                    ColorBytes[i] := Offset + pred(NumGrays) - ColorBytes[i];
                  NormalColor := not NormalColor;
                end;
          end;
        until DispCh in ['X'];
      end;
    'A': goto Bored;
  end;
until PortCh in ['P','S','B','A'];
if RadioCorrect then begin
  SelectGraphicsMode;
  RadiometricCorrect;
  RadioData := true;
end;
if Invert then y := 0 else y := ScreenYMax;
```

```
case PortCh of
  'P','S': OneOrBoth := 1;
  'B': OneOrBoth := 2;
end;
Starboard := PortCh = 'S';
if NumRec <= ScreenYMax then StartRecord := 0
else
  repeat
    ReadLongIntegerDefaultInGraphicsBox(1,3,'Starting record',StartRecord);
    seek(DataFile,StartRecord);
    {$I-} Read(DataFile,StdRec); {$I+}
    AnalyzeRecord;
  until AnswerIsYesXY(1,5,'Display from time ' + TimeString);
seek(DataFile,StartRecord);
OnRecord := StartRecord;
ColsDone := 0;
ScreensDone := 0;
assign(JunkFile,PETMARDefaults.VirtualDiskPath + 'YandRec.txt');
rewrite(JunkFile);
FSplit(FName,Dir,Name,ext);
if CopyImage then begin
  assign(ImageFile,Dir + Name + '.BN1');
  rewrite(ImageFile,succ(ScreenXMax));
  RowCounter := 0;
end;
while (not EOF(DataFile)) do begin
  inc(OnRecord);
  if EOF(DataFile) then goto Bored;
  {$I-} Read(DataFile,StdRec); {$I+}
  if IOResult = 0 then begin
    AnalyzeRecord;
    if (ShowBar) and (OnRecord < 32000) and
      ((OnRecord mod 5) = 0) then
      Screen(1,1,LightRed,Name + ' ' + TimeString + ' Rec: ' +
        IntegerToString(OnRecord,3) +
        ' Spd:' + RealToString(Speed,5,2) + ' kts' +
        ' Rng:' + RealToString(Range,4,0) + ' m' +
        ' Frq:' + IntegerToString(FreqUsed,4) + ' kHz' +
        ' Hdg:' + RealToString(Heading,4,0) + ' øT');
      RecXMax := ScreenXMax div (NumRecs * OneOrBoth);
      FindFishHeight(BottomStart);
      DevFishHeight := abs(OldFishHeight - FishHeight);
      if RadioData and RadioCorrect then
        for x:= BottomStart to 883 do
          if (AvgPrt[x] > 0) and (AvgStd[x] > 0)
            then begin
            StdRec[32 + 2 * x] := round(StdRec[32 + 2 * x] * 32 / AvgPrt[x]);
            StdRec[33 + 2 * x] := round(StdRec[33 + 2 * x] * 32 / AvgStd[x]);
          end;
      if (not RadioData) and RadioCorrect then begin
        ResumeMarker := OnRecord;
        RadiometricCorrect;
        RadioData := true;
        reset(DataFile);
        seek(Datafile,ResumeMarker);
      end;
      if ((DevFishHeight > RecalcParameter) and
        (not (SkipCalcs))) or (OnRecord = 0) then begin
    RecXMax := ScreenXMax div (NumRecs * OneOrBoth);
    SlantRngCorrect;
    XDeflection := (MosaicLoop - 1) * (ScreenXMax div NumRecs);
    case ColsDone of
      1 : XDeflection := ScreenXMax div NumRecs;
      2 : XDeflection := 2 * (ScreenXMax div NumRecs);
    end;
    OldFishHeight := FishHeight;
  end;
  AspectRatioCorrect;
end;
if (KeyPressed and (ReadKey = #27)) or (OnRecord = NumRec) then begin
  repeat
    i := 1;
    MenuStr := '\^Image options\~Resume\~Image\~Get position' +
    '\~Measure distance\^Display preferences\~Express\~Customized\~Abort';
    MenuHelpFileName := 'ss-disp.hlp';
    MakeMenu(MenuStr,-1,-1,ch,i);
    case ch of
      'I' : PETMARImageOption(true,DefaultPrint);
      'G','M': GetPosition;
      'E': begin
            BotVal := 25;
            CopyImage := false;
            SkipCalcs := false;
            RadioCorrect := false;
            RadioData := false;
            ShowBar := false;
            WaitAtBottom := false;
          end;
      'C': begin
            repeat
              i := 99;
              MenuStr := '^Modify preferences' +
                '\~Bottom tracking, ' + ChannelName(BottomChannel) +
                '\~Display status bar, ' + YesOrNo(ShowBar) +
                '\~Edit bottomvalue, ' + IntegerToString(BotVal,3) +
                '\~LUT recalcs skipped, ' + YesOrNo(SkipCalcs) +
                '\~Radiometric corrections, ' + YesOrNo(RadioCorrect) +
                '\~Target color, ';
              if NormalColor then MenuStr := MenuStr + 'White'
              else MenuStr := MenuStr + 'Black';
              MenuStr := MenuStr +
                '\~Wait when screen full, ' + YesOrNo(WaitAtBottom) + '\~Xit';
              MenuHelpFileName := 'ss-modif.hlp';
              MakeMenu(MenuStr,-1,-1,DispCh,i);
              case DispCh of
                'B': begin
                      i := 1;
                      MakeMenu('^Bottom tracking channel\~Port' +
                        '\~Starboard\~Both',5,5,BottomChannel,i);
                    end;
                'D': ShowBar := not ShowBar;
                'E': ReadIntegerDefaultInGraphicsBox(-5,-5,'New bottom value',BotVal);
                'L': SkipCalcs := not SkipCalcs;
                'W': WaitAtBottom := not WaitAtBottom;
                'R': RadioCorrect := not RadioCorrect;
                'T': begin
```

```
                                  for i := 0 to 255 do
                                    ColorBytes[i] := Offset+pred(NumGrays)-ColorBytes[i];
                                    NormalColor := not NormalColor;
                                end;
                            end;
                          until DispCh in ['X'];
                        end;
                    'A': goto Bored;
                  end;
                until ch in ['R','A'];
              end;
            end;
          inc(MosaicLoop);
          OldFishHeight := -9999;
          if FileOpen then begin
            close(DataFile);
            FileOpen := false;
          end;
          close(JunkFile);
        end;
        Bored:;
        if CopyImage then MakeIDXandXYFiles;
      until not AnswerIsYesXY(1,15,'Display this image again');
    end;
    {Bored:;}
    if FileOpen then begin
      close(DataFile);
      FileOpen := false;
    end;
  until ch = 'X';
  assign(DefaultsFile,'SideScan.DEF');
  rewrite(DefaultsFile);
  write(DefaultsFile,SideScanDefaults);
  close(DefaultsFile);
  SelectTextMode;
end;
end.
```